# THE ONTARIO ASSESSMENT INSTRUMENT POOL

# CHEMISTRY I

## SENIOR DIVISION

Ontario

Ministry
of
Education

Hon. Bette Stephenson, M.D., Minister
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CHEMISTRY I
SENIOR DIVISION
ONTARIO ASSESSMENT INSTRUMENT POOL




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This is package number one (of four packages) of assessment materials related to the Ministry of Education curriculum guideline for Chemistry, Senior Division. It consists of: an Introduction, key word lists, instructions for use of laboratory instruments, diagnostic instruments, storyline instruments.

Cost: $15.00 per package

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The Ontario Assessment Instrument Pool (Chemistry) consists of four (4) packages of assessment materials related to the S-17D (1966) and S-17E (1967) Senior Division Chemistry Curricula. Additional materials will be published as they become available.

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|---|---|---|---|

## Chapter 1

### SENIOR CHEMISTRY AND THE OAIP

The Ontario Assessment Instrument Pool consists of a variety of assessment instruments developed to meet the aims, and objectives (stated or implied) in a number of Ministry of Education curriculum guidelines. The instruments published in this Pool were developed for the guidelines, Chemistry, Grade 12, S-17D, 1966 and Chemistry, Grade 13, S-17E, 1967 by secondary school teachers in conjunction with the project directors at Queen's University. The development of the instruments was undertaken in 1978 to meet the terms of a contract established by the Ministry of Education. Information about other programs and courses for which the assessment instruments have been developed, as well as background information on the creation of the OAIP, may be found in the Ministry's publication The Ontario Assessment Instrument Pool: A General Introduction.

The test instruments in the Chemistry Pool have been developed to match the Chemistry guidelines S-17D and S-17E. The distribution of instruments on particular UNITS of study reflect the teaching patterns observed in a survey of Ontario teachers of chemistry. While specific instruments are not listed for other guidelines, teachers are encouraged to select appropriate instruments from the Pool for students taking chemistry at the general level (modified S-17D courses, courses developed from Chemistry RP51, and courses in Industrial Chemistry.) Future

additions to the Chemistry Pool may include instruments which provide broader coverage of chemistry curricula and provide a wider range of levels of difficulty. Since some teachers have indicated expanded coverage of chemistry subject matter in specific areas, instruments have been included to accommodate the needs and interests of students taking advanced and enriched programs.

As it is used here, assessment instrument refers to the smallest unit of the Pool which can be used on its own to assess students' knowledge, understanding, skills, or appreciation of the science of chemistry. The term Pool refers to the entire collection of instruments. The current pool includes a number of examples of each of the following different types of assessment instruments:

Multiple choice

Essay

Diagnostic

Storyline Problems

Laboratory Problems

## Chapter 2

## COMPONENTS OF THE CHEMISTRY POOL

1. Objectives

Objectives were developed for all topics outlined in the S-17D and S-17E guidelines and all objectives are coded to the guideline topics. Their inclusion in Chapters 12 and 13 of this Pool is not meant to imply their general acceptance in all classrooms. Rather, they are intended to assist teachers, and others, to prepare appropriate assessment materials for students.

Objectives are included encompassing skills in the cognitive, affective, and psychomotor domains. However, in this first edition of the Chemistry Pool the majority of the objectives fall within the cognitive domain. The objectives are coded directly to the guidelines. For some guideline sections only one objective was written, while for other sections many objectives were written.

An example of the coding scheme used for the objectives is:

13A.11.1.a(1) At the conclusion of this unit, the student should be able to define van der Waal's forces.

| | | | |
|---|---|---|---|
| 13A | Grade 13 (advanced) | - | S-17E |
| 11 | Unit 11 | - | The Bonding in Solids and Liquids |
| 1 | Subsection 1 | - | The Elements |
| a | Sub- subsection a | - | van der Waal's forces |
| (1) | This last number indicates that this is the first objective written for this guideline item. | | |

2. Instruments

Multiple choice instruments (Chapters 12 and 13) require students to select a correct or most appropriate response from a set of alternative responses. The indicated levels of difficulty found in Chapters 12 and 13 will assist the teacher in choosing instruments appropriate to students in a particular class.

Diagnostic instruments (Chapter 8) are designed to help teachers discover how well students understand some basic concepts in chemistry. The items are intended to permit identification of special individual difficulties and to lead to such remedial steps as seem appropriate.

Essay instruments (Chapter 10) require students to provide an extended response. These include numerical problems. The responses may be free or restricted by precise instructions. The responses may be oral, written, or graphic. Refer to the Intermediate Division English Pool for details on analytical marking and holistic scoring.

Laboratory instruments (Chapter 14) require students to design and describe an experiment, and to suggest alternate solutions. The student is provided with general instructions before the laboratory session. Teachers are provided with instructions for the use of laboratory instruments in Chapter 7.

Storyline instruments (Chapter 9) are interesting, unique, and challenging problems that are designed to arouse the interest of students. The instruments were written as a "pep-up" for use during a study of any topic involving calculations. Storyline instruments are not designed as summative evaluation tools.

NOTES

(a) All multiple choice instruments are coded to the appropriate guidelines, either S-17D or S-17E, but teachers are free to select instruments from either area which are appropriate to the needs of their students. Essay, Diagnostic, Storyline, and Laboratory Instruments have NOT been coded to the S-17D and S-17E guidelines.

(b) The multiple choice instruments are organized for easy guideline reference. The numerical sequence of items starts from 1 for each unit to allow for easy insertion of new instruments into the Pool.

(c) Diagrams are printed in two locations: with the item in the appropriate chapter of the Pool, for those who intend to use printed copy, and in Chapter 8 for those who will use a computer retrieval system. The computer-generated copy of an instrument should be programmed to indicate the need for a particular diagram to be inserted in the printed copy. The diagrams are identified by the notations: $D_1$, $D_2$, ... $D_n$.

(d) Each multiple choice instrument is accompanied by an Identification line (described in the following section).

## 3. Identification Line

The following line is an example of an Identification Line.

12A.4.12 12A.4.3.d.i *** 186 342 823 1185

| | | |
|---|---|---|
| 12A.4.12 | Instrument identification number | |
| | 12A | Grade 12 advanced (S-17D) |
| | 4 | Unit 4 - States of Matter |
| | 12 | Instrument number 12 in unit 4 |
| 12A.4.3.d.i | Guideline reference | |
| | 12A | Grade 12 advanced (S-17D) |
| | 4 | Unit 4 - States of Matter |
| | 3 | Section 3 - Liquids |
| | d | Subsection d - Vapour Pressure |
| | i | Sub-subsection (i) - Pressure exerted by escaped particles when in equilibrium with the liquid. |
| *** | Level of Difficulty indicator | |
| 186 342 823 1185 | Keywords referenced to this item | |

4. Keywords

Keywords are commonly used words or phrases which can be used to locate instruments in the Pool. For example, the keywords:

| | | | |
|---|---|---|---|
| 463 | formula | 840 | -ous, -ic, suffix |
| 796 | nomenclature | 630 | -ite |

could all be used to select the following instrument:

12A.7.3   12A.7.1.c   **   463 796 840 630

12A.7

3) The name corresponding to the formula $Na_2SO_3$ is
- A) sodium sulfide
- B) sodium sulfite
- C) sodium sulfate
- D) sodium sulfur trioxide

The keywords are most suited to use by those who have access to this Pool on computer. The common keyword lists allow teachers to select an instrument for use in either grade 12 or 13, depending on the curricula employed in specific schools. The selection can be by hand or computer search.

The keywords are listed in two formats:

a. Alphabetical Order

The keywords are listed in alphabetical order. The words in the list are numbered so that reference can be made to instruments and guidelines. See Chapter 6.

b. Numerical Order

The keywords are listed in numerical order. The numbered sequence allows users to relate instruments to specific keywords. See Chapter 6.

5. Level of Difficulty Indicator

An estimated difficulty level for each instrument has been provided. This estimate is based on data derived from screening trials in a number of Ontario classrooms. One asterisk (*) identifies an instrument estimated to be easy (more than 75% of students at the appropriate grade levels are likely to choose/give a correct or acceptable response); two asterisks (**) identify an average or moderate instrument (one which between 50% and 75% of students are likely to answer acceptably); and three asterisks (***) identify an instrument classified as difficult (one which fewer than 50% of students are likely to answer acceptably).

It cannot be too strongly stressed that these ratings are estimates rather than rigid and infallible established standards. The estimated difficulty level is saying, in effect, that on the basis of how students have already performed on a particular instrument, the teacher of the "average" class, using the instrument with the grade for which it was screened, might reasonably expect this level of performance. But if the student's first language is not English, if the student is especially gifted, or has particular difficulties, if the instrument has been screened by only a few students, or if any of these or a host of other factors come into play, teachers might not be too surprised by a performance that departs from the values provided. It is the responsibility of the teacher to judge each instrument as to its appropriateness for a particular group of students. Difficulty level is only one of many criteria to be used.

# CHAPTER 3

## UTILIZATION

The assessment instruments in this Pool are intended to supplement the evaluation procedures used by the teacher. It is expected that instruments will be selected on the basis of their relevance to the school program.

Instruments may be used to pre-test students' current knowledge and skills. The same or similar instruments may then be used for post-testintg. Care should be taken, of course, to ensure that the format of the instrument is not interfering with the evaluation process. The teacher may find it necessary to use the same format in a teaching situation so that the students understand what is required of them in dealing with a particular instrument. In addition, when instruments of a higher level of difficulty are used in pre-testing or teaching situations the risk exists that instuments may be reduced to the recall level of difficulty upon repeated usage.

As in the use of any curriculum aid, it is recognized that the effectiveness of the Chemistry Pool will be enhanced if teachers adapt the instruments to their own needs. This may take the form of changing a multiple choice instrument to an open-ended format. In some cases it may take the form of amending or deleting certain responses which the teacher feels inappropriate for a particular class.

The multiple choice questions have been closely analysed and screened for accuracy and language precision. Any alteration by classroom teachers would probably change the level of difficulty and essentially create a new question. There are no distractors of the frivolous or "trick" type in the Pool.

Users of the multiple choice instruments in this Pool must make note that the correct answer to each of the instruments is denoted with an asterisk (*)printed immediately before each correct response. The asterisks (*) must be removed before the instruments are duplicated.

Care should be taken in selecting instruments from the Chemistry Pool for use in summative evaluation, since a few instruments are included that are not specifically referred to within current Ministry guidelines in chemistry.

# CHAPTER 4

## SCREENING PROCEDURES

A rigorous attempt has been made to provide educators with a high quality instrument Pool. The contractors worked closely with teachers and consultants to develop objectives and instruments. These were then screened by other teachers and by students in classrooms throughout Ontario. Subsequent to this screening process, the remaining items were submitted to the Subject Advisory Group. The Subject Advisory Group used the following criteria for accepting, modifying, or rejecting instruments:

acceptable language usage,
acceptable chemistry content and usage,
chemistry safety considerations, and
correct metric SI units.

In addition, statistics involving interim p and d values were used to identify and modify instruments initially unacceptable. The Chemistry Advisory Group also attempted to ensure a realistic coverage of the guidelines S-17D and S-17E, and to ensure the introduction of a variety of instrument types. While initial work on the objectives involved the application of the works of Klopfer[1] and Bloom[2] in an attempt to relate objectives to a

1 L. E. Klopfer. "Evaluation of Learning in Science." In B. S. Bloom; J. T. Hastings; and G.F. Madaus, eds., Handbook on Formative and Summative Evaluation of Student Learning (New York: McGraw-Hill, 1971), pp. 559-641.

2 B. S. Bloom ed., Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook 1. Cognitive domain (New York: McKay, 1956), pp. 201-207.

hierarchy of behavioural learning, instruments in the initial version of the Chemistry Pool are not specifically identified that way.

While the interim statistics are not published in this edition of the Pool, it is anticipated that available p and d values will be published for many of the instruments in the future.

Approval of the Pool by the Chemistry Advisory Group indicates that, in the opinion of the group, the Pool can be used as a means of measuring achievement in chemistry.

In spite of these efforts to provide a high-quality Pool, it is anticipated that errors and discrepancies will appear in print. Users are invited to make comments, criticisms, and recommendations on the use, expansion, and improvement of individual instruments or the entire Pool. Constructive criticisms are appreciated and encouraged. Please direct your comments to:

Ontario Assessment Instrument Pool - Chemistry
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# CHAPTER 6

## KEYWORDS

a) Alphabetical Listing

1 A
2 AC
3 ATP
4 absolute mass
5 absolute zero
6 absorption
7 absorption of energy
8 absorption radiation
35 abundance
9 accuracy
10 acetic acid
11 acid
12 acid anhydride
13 acid catalysis
14 acid rain
15 acid salt
16 acid-base
17 acid-base titration
18 acidic
19 acidic oxide
20 acidic property
21 acidic solution
23 activated complex
24 activation energy
25 activity
26 activity series
27 activity table of metals
28 actual yield
29 addition reaction
30 aggregate
36 air
31 air pressure

32 alchemist
33 alcohol
34 aldehyde
37 alkali
38 alkali metal
39 alkaline earth
40 alkane
46 allotrope
47 alloy
48 alpha
49 alpha particle
50 aluminum
51 amide
52 amine
55 amine
53 amino acid
54 ammeter
56 ammonia
57 ammonium
58 amorphous solid
59 Ampere
60 amphoteric
62 amplitude
63 analysis
22 angle
64 Angstrom
66 angular momentum quantum number
67 anhydride
68 anion
70 anode
71 antacid
72 appearance

73 applied science
74 aqueous
75 aqueous acid solution
76 aqueous solution
77 aquo
78 area
79 argon
80 Aristotle
81 aromatic
82 Arrhenius concept
83 Arrhenius acid-base theory
84 Arrhenius
85 association
87 ate - suffix
88 atmosphere
89 atom
90 atomic
91 atomic mass
93 atomic mass unit
94 atomic number
95 atomic radius
96 atomic size
97 atomic structure
1233 atomic symbol
98 atomic theory
99 attraction
100 attraction - repulsion
101 Aufbau principle
102 Avogadro
103 Avogadro's Number
104 Avogadro's Principle
105 Avogadro's hypothesis
106 balanced equation
107 balancing equation
108 Balmer series
109 barium
110 barometer
111 base
112 basic
113 basic anhydride
114 basic oxide
115 basic property
116 basic solution
117 battery
119 benzene
120 beryllium
121 beta
122 beta particle
124 billiard-ball theory
125 binary acid
126 binary compound
127 binding energy
128 biochemistry
129 bleaching
130 Bohr model
131 Bohr
132 Bohr-Rutherford diagram
133 boiler scale
134 boiling
135 boiling point
136 boiling point determination
41 bond
137 bond angle
138 bond breaking
140 bond dissociation
141 bond dissociation energy
142 bond energy
143 bond formation
144 bond length
145 bond representation
146 bond strength
1268 bond types

223 clock reaction
224 closed system
61 coagulate
226 coal
227 coefficient
228 coke
230 collision theory
231 collision theory
- concentration effect
232 collision theory
- temperature effect
233 colloid
234 colour
235 colour intensity
236 colour of solution
237 colorimetric
238 combination
239 combination reaction
240 combustion
242 common ion effect
243 competition for electrons
244 complete combustion
1281 completion
245 complex
246 complex ion
247 complex salt
248 composition
249 compound
250 compound ion
65 compressibility
251 concentrated
252 concentration
253 concentration of solution
254 concept
255 conclusion
256 condensation
258 conductance
259 conductivity
260 conductor
261 conjugate pair
262 conservation of mass-energy
263 constant
265 continuous line spectrum
266 control
267 convection current
268 cooling curve
270 coordinate ion
271 coordination
272 coordination number
273 coordination sphere
274 copper
275 corrosion
276 Coulomb
277 covalence
278 covalent
279 covalent bond
280 covalent character
281 covalent crystal
282 covalent network
283 covalent radii
284 cracking
285 crystal
286 crystal lattice
287 crystal pattern
288 crystal structure
289 crystalline
290 crystallization
292 cyclic hydrocarbons
294 DC
295 DNA
297 d orbital
299 Dalton

298 Dalton's Law of Partial Pressure
1252 Dalton's Theory of the Atom
300 data
301 Davey
302 decomposition
303 decomposition reaction
304 decreased
69 description
305 deductive reasoning
306 degree of ionization
307 degree of randomness
308 dehydration
309 deliquescence
310 delta G ($\triangle G$)
311 delta H ($\triangle H$)
312 delta S ($\triangle S$)
313 Democritus
314 denaturation
315 density
316 derivative
317 desiccant
318 desiccator
319 detergent
320 deuterium
321 deuterium oxide
322 di - prefix
323 diameter
324 diamond
325 diatomic
327 diffraction
328 diffraction pattern
329 diffusion
330 dilute
331 dilution of stock solution
332 dipole
333 dipole-dipole force
334 diprotic
335 direction
336 direction of electron flow
337 direction of ion flow
338 discharge tube
339 displacement
341 dissociation
342 dissociation constant
343 dissolving
345 distillation
346 double bond
348 dry cell
349 drying agent
350 $dsp^2$
351 dynamic equilibrium
352 dynamic state
353 $E^o$
354 $E = mc^2$
355 E cell
356 ecology
357 efflorescence
358 elastic collision
359 electric charge
360 electric current
362 electric field
364 electrical
363 electrical conduction
365 electricity
366 electrochemical series
367 electrochemistry
368 electrode
369 electrolysis
370 electrolyte
371 electrolytic cell

372 electrolytic conductor
373 electrolytic solution
374 electromagnetic radiation
375 electromagnetic wave
376 electron
377 electron acceptor
378 electron affinity
1250 electron configuration
380 electron distribution
381 electron donor
382 electron dot
86 electron microscope
383 electron pair
384 electron shell
385 electron spin
386 electron transfer
92 electron volt
1269 electron withdrawing group
387 electronegativity
388 electronic arrangement
391 electroplating
392 electropositivity
393 electrostatic force
394 electrovalence
395 element
396 elimination reaction
397 emission spectrum
400 empirical
401 empirical formula
402 emulsion
403 end point
404 endothermic
405 energy
406 energy change
408 energy level
409 energy source
410 energy sublevel
411 enthalpy
412 entropy
413 enzyme
414 equation
1256 equation problems
415 equilibrium
416 equilibrium composition
417 equilibrium concentration
418 equilibrium concept
419 equilibrium constant expression
420 equilibrium expression
421 equilibrium law
423 equilibrium shift
425 equivalence point
1251 error calculations
426 ester
427 ether
429 eudiometer
430 evaporation
431 evolution of energy
432 excess
433 excited state
434 exothermic
435 expansion
436 experiment
437 experimental condition
438 experimental data
439 experimental error
440 exponential notation
442 f orbital
443 factor
444 Fahrenheit thermometer
445 family
447 Faraday

446 Faraday's law of electrolysis
448 fast reaction
449 fat
450 fatty acid
453 fission
454 fixed nitrogen
455 flame test
456 flammable
457 fluid
458 fluorescence
459 fluorine
460 force
461 formation
462 formic acid
463 formula
464 forward reaction
465 fossil fuel
466 fractional distillation
468 freezing
469 freezing point
470 frequency
471 frequency of rotation
472 frequency of vibration
473 fuel
474 fuel cell
475 function of protein
476 functional group
478 fundamental particle
479 fused
480 fusion
481 gain of electrons
482 galvanic cell
483 gamma particle
484 gas
118 gas constant
485 gas evolution
486 gas law
487 gas pressure
1235 Gay-Lussac's Law
488 Gay-Lussac's Law of Combining Gas Volumes
489 geometric isomer
490 geometry
492 glycerine
494 glycol
495 Graham's Law
496 gram atomic mass
497 gram molecular mass
498 graph
499 graphite
500 gravity
501 ground state
502 ground water
503 group
504 group 2
506 gypsum
507 competition
508 Haber process
509 half reaction
510 half-cell
511 half-cell balancing method
512 half-cell potential
513 half-life
514 halide
515 halogen
516 hard
517 hard water
518 hardness
519 health
1240 heat
520 heat capacity

657 Law of Conservation of Energy
658 Law of Conservation of Mass
659 Law of Constant Composition
660 Law of Definite Proportions
661 Law of Multiple Proportions
662 Law of chemical equilibrium
663 Law of combining gas volumes
664 Law of mass action
665 Le Chatelier's principle
666 lemon juice
667 length
668 Lewis acid
669 Lewis base
670 Lewis dot
671 Lewis
1242 life
672 ligand
673 light
674 limewater
676 limiting reagent
677 line diagram
678 line spectrum
679 linear molecule
680 liquid
681 liquid air
683 litmus
684 litre
685 lobe
686 lone pair
688 loss of electrons
689 luminosity
690 lustre
691 lye
692 Lyman
693 $m_l$ - quantum number
694 $m_s$ - quantum number
695 macroscopic properties
696 magnesium
697 magnetic field
698 magnetic quantum number
699 manganese
700 manometer
701 mass determination
702 mass balance
703 mass number
704 mass spectrograph
705 mass spectrometer
706 mass spectrum
707 matter
709 maximum
708 maximum disorder
710 measurement
711 measurement of crystal structure
712 mechanical mixture
713 mechanism
714 media
715 melting
716 melting point
717 melting point determination
718 melting point tube
719 Mendeleev
720 mercury
721 meta - prefix
722 metal

794 noble gas
795 node
796 nomenclature
797 non aqueous
798 non chemical mechanism
800 non electrolyte
801 non metal
802 non polar
805 nuclear
803 nuclear atom
804 nuclear binding energy
806 nuclear charge
807 nuclear energy
808 nuclear equations
809 nuclear particle
810 nuclear policy
811 nuclear reaction
812 nuclear reactor
813 nuclear stability
814 nucleic acid
815 nucleus
816 number of atoms
817 nylon
818 observation
819 occurrence
820 octahedron
821 octet
822 octet rule
825 operation
826 operational definition
1265 optical activity
827 optimum yield
828 orbit
829 orbital
830 orbital box representation
831 orbital diagram
832 orbital occupancy
833 order of addition
834 organic
835 organic chemistry
836 organic compound
837 organic resource
838 organometallic
839 ortho - prefix
840 ous, ic - suffix
841 outer shell
842 overall cell reaction
843 oxidation
844 oxidation number
845 oxidation number balancing method
846 oxidation state
847 oxide
848 oxide coating
849 oxidize
850 oxidizing agent
851 oxidizing strength
852 oxyacid
853 oxygen
854 ozone
855 p orbital
856 pH
857 pK
858 pOH
859 packing
860 para - prefix
861 partial pressure
1286 pascal
862 Pauli exclusion principle
863 Pauli
865 peptide bond
866 percent by mass

867 percent composition by mass
868 percent composition by volume
869 percentage composition
870 percentage dissociation
871 percentage yield
872 period
873 Periodic Table
874 periodicity
875 permanent hardness
876 peroxide
877 petrochemical
878 petroleum
879 phase
880 phase change
881 phenolphthalein
882 phlogiston
883 phosphate
884 phosphite
885 phosphoric acid
886 phosphorus
887 photoelectric effect
888 photon
889 photosynthesis
890 physical change
891 physical property
892 pipet
893 Planck
894 Planck's constant
895 plaster of Paris
896 plastic
897 plum pudding atom
898 polar bond
899 polar covalent compound
900 polar molecule
901 polarity
902 pollution
903 polyamide
905 polyester
906 polymer
908 polyprotic
909 positive charge
910 positive ion
911 potential
912 potential difference
913 potential energy
914 potential energy diagram
915 precipitate
916 precision
917 prefix
918 pressure
919 pressure effect on boiling point
920 Priestley
921 principle quantum number
922 probability distribution
923 producer gas
924 product
926 production
927 products favoured
928 property
1271 properties of liquids and solids
929 protein
930 protein synthesis
932 proton
1261 proton acceptor
1262 proton doner
933 proton-transfer
934 pure
936 pure science

937 pure substance
938 purification
939 purity
1282 $PV = nRT$
940 $Q = mc\Delta t$
941 qualitative
942 qualitative analysis
943 quantitative
944 quantitative analysis
945 quantitative composition
946 quanta
947 quantum
948 quantum jump
151 quantum mechanics
949 quantum number
950 quicklime
951 RNA
952 R = functional group
953 radiation
954 radical
955 radio waves
956 radioactive
957 radioactive decay
1258 radioactive tracer
958 radiocarbon dating
959 radioisotope
960 radium
961 raisin bun model
962 randomness
963 range of reactivities
964 rare earth
967 rate
965 rate constant
966 rate determining step
968 rate of decay
969 rate of dissolving
970 rate of precipitation
971 rate of reaction
972 rate of solution
973 rate equation
974 rate concentration relationship
975 rate temperature relationship
1239 ratio
976 ratio of ions
977 reactant
978 reactants favoured
979 reaction
980 reaction coordinate
981 reaction of alcohol
1259 reaction mechanism
982 reaction order
983 reaction with acid
984 reaction with air or oxygen
985 reaction with water
986 reactivity
987 real gas
988 redox
989 redox reaction
990 reducing agent
991 reducing strength
992 reduction
993 reduction potential
994 reference electrode
995 relative atomic mass
996 relative strength
997 relative mass
998 replacement
999 repulsion
1000 respiration

1001 reverse reaction
1002 reversibility
1003 reversible reaction
1004 role of government
1005 role of society
1241 room temperature
1006 rotational energy
1007 rotational motion
177 rule
1008 rust
1009 Rutherford gold foil
1010 Rutherford atomic model
1011 Rutherford
1012 Rydberg constant
1013 Rydberg equation
1014 SI
1015 STP
1016 s bond
1017 s orbital
1018 s-p bonding
1020 sacrificial anode
1021 safety
1022 salt
1023 salt-bridge
1024 saturated hydrocarbon
1025 saturated solution
1026 saturation
1027 scattering
1028 schematic diagram
1029 Schrodinger
1030 science
1031 scientific method
1032 scientific model
1033 second
1034 second law of thermodynamics
1035 seed crystal
1264 selective precipitation
1036 separation
1037 shape
1038 shell
178 shielding effect
1039 significant figure
1040 silicon
179 silver
1041 simplest formula
1042 single bond
1043 single covalent bond
1044 skeleton equation
1045 slow oxidation
1046 slow reaction
1047 soap
1048 society
1049 sodium
1050 sodium hydroxide
1051 soft acid
1052 soft water
1053 solid
1054 solubility
1055 solubility equilibrium
1057 solubility of gases
1058 solubility product constant
1059 solute
1060 solute-solvent interaction
1061 solution
1063 solvation
1064 solvent
1066 source
1067 source of oxygen
1068 sp
1069 $sp^3$
1070 space

1071 specific gravity
1072 specific heat
1073 spectator ion
1074 spectroscopy
1075 spectrum
1076 speed
1077 speed of light
1078 spin
1079 spin quantum number
1080 spontaneous
1081 spontaneous combustion
1082 spontaneous reaction
1083 stability
1255 stable electron configuration
1086 standard conditions
1087 standard electrode
1088 standard half-cell
1089 standard half-cell potential
1090 standard solution
1091 standardization
1093 starch
1094 state change
1095 state of equilibrium
1096 state of matter
1097 stationary state
1098 steady state
1099 stereochemistry
1100 stock
1101 stoichiometry
1102 storage battery
1103 straight chain
1104 strength
1105 strong acid
1106 strong base
1107 strong electrolyte
1108 strontium
1109 structural diagram
1110 structural formula
1111 structural unit
1112 structure
1114 sub-level
1115 sublimation
1116 sublime
1117 substance
1118 substitution reaction
1119 sugar
1273 sulfate
1274 sulfate ion
1275 sulfite
1276 sulfur
1277 sulfuric acid
1278 sulfurous acid
1120 sulphate
1121 sulphate ion
1122 sulphite
1123 sulphur
1124 sulphuric acid
1278 sulphurous
1125 supercooling
1126 supersaturated
1127 surface area effect
1128 surface water
1130 symbol
1132 symmetry
1133 synthesis
1134 synthetic
1136 system
1137 technology
1138 temperature
1139 temperature change

1213 water of crystallization
1214 water of hydration
1216 water softener
1217 water gas
1218 wave function
1219 wave mechanical model
1220 wave particle duality
196 wax
1221 wavelength
1222 weak acid
1223 weak base
1224 weak electrolyte
1225 weight
1226 word equation
1227 work
1228 X-ray
1229 yield
1230 Z
1231 zeolite
1232 zinc

## KEYWORDS

b) Numerical Listing

| | | | |
|---|---|---|---|
| 1 | A | 35 | abundance |
| 2 | AC | 36 | air |
| 3 | ATP | 37 | alkali |
| 4 | absolute mass | 38 | alkali metal |
| 5 | absolute zero | 39 | alkaline earth |
| 6 | absorption | 40 | alkane |
| 7 | absorption of energy | 41 | bond |
| 8 | absorption radiation | 42 | Brownian motion |
| 9 | accuracy | 43 | candle |
| 10 | acetic acid | 44 | carbon tetrachloride |
| 11 | acid | 45 | cathode protection |
| 12 | acid anhydride | 46 | allotrope |
| 13 | acid catalysis | 47 | alloy |
| 14 | acid rain | 48 | alpha |
| 15 | acid salt | 49 | alpha particle |
| 16 | acid-base | 50 | aluminum |
| 17 | acid-base titration | 51 | amide |
| 18 | acidic | 52 | amine |
| 19 | acidic oxide | 53 | amino acid |
| 20 | acidic property | 54 | ammeter |
| 21 | acidic solution | 55 | amine |
| 22 | angle | 56 | ammonia |
| 23 | activated complex | 57 | ammonium |
| 24 | activation energy | 58 | amorphous solid |
| 25 | activity | 59 | Ampere |
| 26 | activity series | 60 | amphoteric |
| 27 | activity table of metals | 61 | coagulate |
| 28 | actual yield | 62 | amplitude |
| 29 | addition reaction | 63 | analysis |
| 30 | aggregate | 64 | Angstrom |
| 31 | air pressure | 65 | compressibility |
| 32 | alchemist | 66 | angular momentum quantum number |
| 33 | alcohol | 67 | anhydride |
| 34 | aldehyde | 68 | anion |

69 description
70 anode
71 antacid
72 appearance
73 applied science
74 aqueous
75 aqueous acid solution
76 aqueous solution
77 aquo
78 area
79 argon
80 Aristotle
81 aromatic
82 Arrhenius concept
83 Arrhenius acid-base theory
84 Arrhenius
85 association
86 electron microscope
87 ate - suffix
88 atmosphere
89 atom
90 atomic
91 atomic mass
92 electron volt
93 atomic mass unit
94 atomic number
95 atomic radius
96 atomic size
97 atomic structure
98 atomic theory
99 attraction
100 attraction - repulsion
101 Aufbau principle
102 Avogadro
103 Avogadro's Number
104 Avogadro's Principle
105 Avogadro's hypothesis
106 balanced equation
107 balancing equation
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109 barium
110 barometer
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113 basic anhydride
114 basic oxide
115 basic property
116 basic solution
117 battery
118 gas constant
119 benzene
120 beryllium
121 beta
122 beta particle
123 ice
124 billiard-ball theory
125 binary acid
126 binary compound
127 binding energy
128 biochemistry
129 bleaching
130 Bohr model
131 Bohr
132 Bohr-Rutherford diagram
133 boiler scale
134 boiling
135 boiling point
136 boiling point determination
137 bond angle
138 bond breaking
139 IUPAC
140 bond dissociation

141 bond dissociation energy
142 bond energy
143 bond formation
144 bond length
145 bond representation
146 bond strength
147 bonding
148 nitrogen
149 bonding capacity
151 quantum mechanics
150 bonding energy
152 Boyle's Law
153 Bragg
154 branched molecule
155 bromine
156 bromothymol blue
157 Bronsted acid
158 Bronsted base
159 Bronsted-Lowry
160 buffer
161 buret
162 c (speed of light)
163 CANDU
164 calcium
165 calorimeter
166 calorimetry
167 carbohydrate
168 carbohydrate metabolism
169 carbon
170 carbon 12
171 carbon 14
172 carbon dioxide
173 carbon monoxide
174 carbon skeleton
175 carbonaceous
176 carbonate
177 rule
178 shielding effect
179 silver
180 time
181 catalyst
182 catalytic effect
183 vacuum
184 cathode
185 cathode ray
186 cathode ray tube (crt)
187 cation
188 cellulose
189 Celsius scale
190 Celsius thermometer
191 Chadwick
192 chain reaction
193 change in binding energy
194 change in free energy
195 vapour
196 wax
197 change in pressure
198 change in temperature
199 change in volume
200 charge
201 charge balance
202 charge to mass ratio
203 Charles' Law
204 chelate
205 chemical activity
206 chemical bond
207 chemical change
208 chemical energy
209 chemical equation
210 chemical equilibrium
211 chemical formula
213 chemical property

214 chemical reaction
215 chemical reactivity
216 chemistry
218 chloride
219 chlorine
220 chromium
221 cis-trans isomerism
222 classification
223 clock reaction
224 closed system
226 coal
227 coefficient
228 coke
230 collision theory
231 collision theory
- concentration effect
232 collision theory
- temperature effect
233 colloid
234 colour
235 colour intensity
236 colour of solution
237 colorimetric
238 combination
239 combination reaction
240 combustion
242 common ion effect
243 competition for electrons
244 complete combustion
245 complex
246 complex ion
247 complex salt
248 composition
249 compound
250 compound ion
251 concentrated
252 concentration
253 concentration of solution
254 concept
255 conclusion
256 condensation
258 conductance
259 conductivity
260 conductor
261 conjugate pair
262 conservation of mass-energy
263 constant
265 continuous line spectrum
266 control
267 convection current
268 cooling curve
270 coordinate ion
271 coordination
272 coordination number
273 coordination sphere
274 copper
275 corrosion
276 Coulomb
277 covalence
278 covalent
279 covalent bond
280 covalent character
281 covalent crystal
282 covalent network
283 covalent radii
284 cracking
285 crystal
286 crystal lattice
287 crystal pattern
288 crystal structure
289 crystalline
290 crystallization

292 cyclic hydrocarbons
294 DC
295 DNA
297 d orbital
298 Dalton's Law of Partial Pressure
299 Dalton
300 data
301 Davey
302 decomposition
303 decomposition reaction
304 decreased
305 deductive reasoning
306 degree of ionization
307 degree of randomness
308 dehydration
309 deliquescence
310 delta G ($\triangle$G)
311 delta H ($\triangle$H)
312 delta S ($\triangle$S)
313 Democritus
314 denaturation
315 density
316 derivative
317 desiccant
318 desiccator
319 detergent
320 deuterium
321 deuterium oxide
322 di - prefix
323 diameter
324 diamond
325 diatomic
327 diffraction
328 diffraction pattern
329 diffusion
330 dilute
331 dilution of stock solution
332 dipole
333 dipole-dipole force
334 diprotic
335 direction
336 direction of electron flow
337 direction of ion flow
338 discharge tube
339 displacement
341 dissociation
342 dissociation constant
343 dissolving
345 distillation
346 double bond
348 dry cell
349 drying agent
350 $dsp^2$
351 dynamic equilibrium
352 dynamic state
353 $E^o$
354 $E = mc^2$
355 E cell
356 ecology
357 efflorescence
358 elastic collision
359 electric charge
360 electric current
362 electric field
363 electrical conduction
364 electrical
365 electricity
366 electrochemical series
367 electrochemistry
368 electrode
369 electrolysis

370 electrolyte
371 electrolytic cell
372 electrolytic conductor
373 electrolytic solution
374 electromagnetic radiation
375 electromagnetic wave
376 electron
377 electron acceptor
378 electron affinity
380 electron distribution
381 electron donor
382 electron dot
383 electron pair
384 electron shell
385 electron spin
386 electron transfer
387 electronegativity
388 electronic arrangement
391 electroplating
392 electropositivity
393 electrostatic force
394 electrovalence
395 element
396 elimination reaction
397 emission spectrum
400 empirical
401 empirical formula
402 emulsion
403 end point
404 endothermic
405 energy
406 energy change
408 energy level
409 energy source
410 energy sublevel
411 enthalpy
412 entropy
413 enzyme
414 equation
415 equilibrium
416 equilibrium composition
417 equilibrium concentration
418 equilibrium concept
419 equilibrium constant expression
420 equilibrium expression
421 equilibrium law
423 equilibrium shift
425 equivalence point
426 ester
427 ether
429 eudiometer
430 evaporation
431 evolution of energy
432 excess
433 excited state
434 exothermic
435 expansion
436 experiment
437 experimental condition
438 experimental data
439 experimental error
440 exponential notation
442 f orbital
443 factor
444 Fahrenheit thermometer
445 family
447 Faraday
446 Faraday's law of electrolysis
448 fast reaction
449 fat

450 fatty acid
453 fission
454 fixed nitrogen
455 flame test
456 flammable
457 fluid
458 fluorescence
459 fluorine
460 force
461 formation
462 formic acid
463 formula
464 forward reaction
465 fossil fuel
466 fractional distillation
468 freezing
469 freezing point
470 frequency
471 frequency of rotation
472 frequency of vibration
473 fuel
474 fuel cell
475 function of protein
476 functional group
478 fundamental particle
479 fused
480 fusion
481 gain of electrons
482 galvanic cell
483 gamma particle
484 gas
485 gas evolution
486 gas law
487 gas pressure
488 Gay-Lussac's Law of Combining Gas Volumes
489 geometric isomer
490 geometry
492 glycerine
494 glycol
495 Graham's Law
496 gram atomic mass
497 gram molecular mass
498 graph
499 graphite
500 gravity
501 ground state
502 ground water
503 group
504 group 2
506 gypsum
507 competition
508 Haber process
509 half reaction
510 half-cell
511 half-cell balancing method
512 half-cell potential
513 half-life
514 halide
515 halogen
516 hard
517 hard water
518 hardness
519 health
520 heat capacity
521 heat change
522 heat content
523 heat exchange
524 heat of a reaction
525 heat of combustion
526 heat of decomposition
527 heat of dilution

528 heat of formation
529 heat of ionization
530 heat of neutralization
531 heat of reaction
532 heat of solution
533 heat transfer
534 heating curve
535 heavy water
536 helium
537 Henry's Law
538 Hess' law
540 heterogeneous
542 historical development
543 Hoffman Apparatus
544 homogeneous
547 household acid
548 household base
549 Hund's rule
551 hybrid orbital
552 hydrate
553 hydrated ion
554 hydration
555 hydro prefix
556 hydrocarbon
557 hydrogen
558 hydrogen atom
559 hydrogen bond
560 hydrogen bonding effect
561 hydrogen gas
562 hydrogen ion
563 hydrogen spectrum
564 hydrolysis
565 hydrometer
566 hydronium ion
567 hydroxide
568 hydroxyl ion
569 hygroscopic
570 hypo
571 hypo prefix
573 hypothesis
574 IR
575 IR spectrum
576 IUPAC
577 ic - suffix
578 ide - suffix
579 ideal gas
580 ignition temperature
581 immiscible
582 importance
583 incomplete reaction
584 increased
585 indicator
586 inductive reasoning
587 industry
588 inert gas
589 inert
590 infrared spectroscopy
591 initial concentration
592 initial state
593 inorganic
594 inorganic acid
595 insoluble
596 insulator
597 intermolecular force
598 interpolation
599 intramolecular
600 inverse square law
601 inversion
602 iodate
603 iodide
604 iodine
605 ion

606 ion exchange
608 ion interaction
609 ion migration
610 ion product
611 ionic bond
612 ionic character
613 ionic compound
614 ionic crystal
615 ionic dissociation
616 ionic radius
617 ionic solid
618 ionic solution
619 ionic valence
620 ionization
621 ionization energy
622 ionization potential
624 iron
625 isolate
626 isomer
627 isomerism
628 isotope
629 isotopic tracing
630 ite - suffix
631 Joule
632 K
633 $K_a$
634 $K_b$
635 $K_c$
636 $K_p$
637 $K_{sp}$
638 $K_w$
639 Kelvin scale
640 ketone
641 kilo
642 kindling temperature
643 kinetic energy
644 kinetic energy distribution
645 kinetic molecular theoy
646 kinetic theory
647 l - quantum number
648 laboratory
649 laboratory production
650 lanthanides
651 lattice
652 lattice energy
654 Lavoisier
655 law
656 Law of Additivity of Reaction Heats
657 Law of Conservation of Energy
658 Law of Conservation of Mass
659 Law of Constant Composition
660 Law of Definite Proportions
661 Law of Multiple Proportions
662 Law of chemical equilibrium
663 Law of combining gas volumes
664 Law of mass action
665 Le Chatelier's principle
666 lemon juice
667 length
668 Lewis acid
669 Lewis base
670 Lewis dot
671 Lewis
672 ligand
673 light
674 limewater
676 limiting reagent
677 line diagram
678 line spectrum
679 linear molecule

680 liquid
681 liquid air
683 litmus
684 litre
685 lobe
686 lone pair
687 Kelvin
688 loss of electrons
689 luminosity
690 lustre
691 lye
692 Lyman
693 $m_l$ - quantum number
694 $m_s$ - quantum number
695 macroscopic properties
696 magnesium
697 magnetic field
698 magnetic quantum number
699 manganese
700 manometer
701 mass determination
702 mass balance
703 mass number
704 mass spectrograph
705 mass spectrometer
706 mass spectrum
707 matter
708 maximum disorder
709 maximum
710 measurement
711 measurement of crystal structure
712 mechanical mixture
713 mechanism
714 media
715 melting
716 melting point
717 melting point determination
718 melting point tube
719 Mendeleev
720 mercury
721 meta - prefix
722 metal
723 metal oxide
724 metallic
725 metallic bonding
726 metallic conductor
727 metallic element
728 metallic salt
729 metallic valence
730 metalloid
731 method of preparation
732 microscopic - properties
733 microwave
735 Millikan oil drop
736 mineral acid
737 minimum energy
738 miscible
739 mixture
741 model
742 moderator
743 modern theory of electrolytes
744 Mohr hardness scale
745 molality
746 molar concentration
747 molar
748 molar heat
749 molar mass
750 molar volume
751 mole
752 molecular

753 molecular architecture
754 molecular crystal
755 molecular enthalpy
756 molecular formula
757 molecular mass
758 molecular motion
759 molecular orbital
760 molecular size
761 molecular solid
762 molecular velocity
763 molecularity
764 molecule
765 molten
766 monatomic
767 monobasic
768 monomer
769 monoprotic
770 mortar and pestle
771 Moseley
772 multiple covalent bond
773 multiple
774 NMR
775 n - quantum number
776 name from formula
777 natural occurrence
778 nearest neighbour
779 negative charge
780 negative ion
781 Nernst equation
782 net direction
783 net ionic equation
784 network solid
785 neutral
787 neutralization
788 neutron
789 neutron/proton ratio
790 nickel
791 nitrate
792 nitric acid
793 nitrite
794 noble gas
795 node
796 nomenclature
797 non aqueous
798 non chemical mechanism
800 non electrolyte
801 non metal
802 non polar
803 nuclear atom
804 nuclear binding energy
805 nuclear
806 nuclear charge
807 nuclear energy
808 nuclear equations
809 nuclear particle
810 nuclear policy
811 nuclear reaction
812 nuclear reactor
813 nuclear stability
814 nucleic acid
815 nucleus
816 number of atoms
817 nylon
818 observation
819 occurrence
820 octahedron
821 octet
822 octet rule
825 operation
826 operational definition
827 optimum yield
828 orbit

829 orbital
830 orbital box representation
831 orbital diagram
832 orbital occupancy
833 order of addition
834 organic
835 organic chemistry
836 organic compound
837 organic resource
838 organometallic
839 ortho - prefix
840 ous, ic - suffix
841 outer shell
842 overall cell reaction
843 oxidation
844 oxidation number
845 oxidation number balancing method
846 oxidation state
847 oxide
848 oxide coating
849 oxidize
850 oxidizing agent
851 oxidizing strength
852 oxyacid
853 oxygen
854 ozone
855 p orbital
856 pH
857 pK
858 pOH
859 packing
860 para - prefix
861 partial pressure
862 Pauli exclusion principle
863 Pauli
865 peptide bond
866 percent by mass
867 percent composition by mass
868 percent composition by volume
869 percentage composition
870 percentage dissociation
871 percentage yield
872 period
873 Periodic Table
874 periodicity
875 permanent hardness
876 peroxide
877 petrochemical
878 petroleum
879 phase
880 phase change
881 phenolphthalein
882 phlogiston
883 phosphate
884 phosphite
885 phosphoric acid
886 phosphorus
887 photoelectric effect
888 photon
889 photosynthesis
890 physical change
891 physical property
892 pipet
893 Planck
894 Planck's constant
895 plaster of Paris
896 plastic
897 plum pudding atom
898 polar bond

899 polar covalent compound
900 polar molecule
901 polarity
902 pollution
903 polyamide
905 polyester
906 polymer
908 polyprotic
909 positive charge
910 positive ion
911 potential
912 potential difference
913 potential energy
914 potential energy diagram
915 precipitate
916 precision
917 prefix
918 pressure
919 pressure effect on boiling point
920 Priestley
921 principle quantum number
922 probability distribution
923 producer gas
924 product
926 production
927 products favoured
928 property
929 protein
930 protein synthesis
932 proton
933 proton-transfer
934 pure
936 pure science
937 pure substance
938 purification
939 purity
940 $Q = mc\triangle t$
941 qualitative
942 qualitative analysis
943 quantitative
944 quantitative analysis
945 quantitative composition
946 quanta
947 quantum
948 quantum jump
949 quantum number
950 quicklime
951 RNA
952 R = functional group
953 radiation
954 radical
955 radio waves
956 radioactive
957 radioactive decay
958 radiocarbon dating
959 radioisotope
960 radium
961 raisin bun model
962 randomness
963 range of reactivities
964 rare earth
965 rate constant
966 rate determining step
967 rate
968 rate of decay
969 rate of dissolving
970 rate of precipitation
971 rate of reaction
972 rate of solution
973 rate equation
974 rate concentration - relation

975 rate temperature relationship
976 ratio of ions
977 reactant
978 reactants favoured
979 reaction
980 reaction coordinate
981 reaction of alcohol
982 reaction order
983 reaction with acid
984 reaction with air or oxygen
985 reaction with water
986 reactivity
987 real gas
988 redox
989 redox reaction
990 reducing agent
991 reducing strength
992 reduction
993 reduction potential
994 reference electrode
995 relative atomic mass
996 relative strength
997 relative mass
998 replacement
999 repulsion
1000 respiration
1001 reverse reaction
1002 reversibility
1003 reversible reaction
1004 role of government
1005 role of society
1006 rotational energy
1007 rotational motion
1008 rust
1009 Rutherford gold foil
1010 Rutherford atomic model
1011 Rutherford
1012 Rydberg constant
1013 Rydberg equation
1014 SI
1015 STP
1016 s bond
1017 s orbital
1018 s-p bonding
1020 sacrificial anode
1021 safety
1022 salt
1023 salt-bridge
1024 saturated hydrocarbon
1025 saturated solution
1026 saturation
1027 scattering
1028 schematic diagram
1029 Schrodinger
1030 science
1031 scientific method
1032 scientific model
1033 second
1034 second law of thermodynamics
1035 seed crystal
1036 separation
1037 shape
1038 shell
1039 significant figure
1040 silicon
1041 simplest formula
1042 single bond
1043 single covalent bond
1044 skeleton equation
1045 slow oxidation

1046 slow reaction
1047 soap
1048 society
1049 sodium
1050 sodium hydroxide
1051 soft acid
1052 soft water
1053 solid
1054 solubility
1055 solubility equilibrium
1057 solubility of gases
1058 solubility product constant
1059 solute
1060 solute-solvent interaction
1061 solution
1063 solvation
1064 solvent
1066 source
1067 source of oxygen
1068 sp
1069 $sp^3$
1070 space
1071 specific gravity
1072 specific heat
1073 spectator ion
1074 spectroscopy
1075 spectrum
1076 speed
1077 speed of light
1078 spin
1079 spin quantum number
1080 spontaneous
1081 spontaneous combustion
1082 spontaneous reaction
1083 stability
1086 standard conditions
1087 standard electrode
1088 standard half-cell
1089 standard half-cell potential
1090 standard solution
1091 standardization
1093 starch
1094 state change
1095 state of equilibrium
1096 state of matter
1097 stationary state
1098 steady state
1099 stereochemistry
1100 stock
1101 stoichiometry
1102 storage battery
1103 straight chain
1104 strength
1105 strong acid
1106 strong base
1107 strong electrolyte
1108 strontium
1109 structural diagram
1110 structural formula
1111 structural unit
1112 structure
1114 sub-level
1115 sublimation
1116 sublime
1117 substance
1118 substitution reaction
1119 sugar
1120 sulphate
1121 sulphate ion
1122 sulphite
1123 sulphur

1124 sulphuric acid
1125 supercooling
1126 supersaturated
1127 surface area effect
1128 surface water
1130 symbol
1132 symmetry
1133 synthesis
1134 synthetic
1136 system
1137 technology
1138 temperature
1139 temperature change
1140 temperature effect
1141 temperature effect on vapour pressure
1142 temporary hardness
1143 test
1144 tetrahedral
1145 tetrahedron
1146 theoretical yield
1147 theory
1148 thermochemical equation
1149 thermodynamics
1150 thermometer
1151 thermonuclear reaction
1152 third row
1153 Thomson
1154 Thomson atomic model
1155 threshold energy
1156 titrant
1157 titration
1158 titration curve
1159 titration technique
1160 titre
1161 tracer
1162 trades
1163 transition element
1164 transition energy
1165 translational energy
1166 translational motion
1167 trend
1171 triatomic
1172 tribasic
1173 triple bond
1174 triple covalent bond
1175 tritium
1176 true formula
1177 type
1180 UV
1181 u
1182 uncertainty principle
1184 units
1185 unknown
1186 unpaired electrons
1187 unreacted
1188 unsaturated hydrocarbon
1189 unsaturated solution
1190 universal wave equation
1191 uses
1192 valence
1193 valence electron
1194 valence level
1195 valence shell
1196 van der Waal's radius
1197 van der Waal's force
1198 vapourization - pressure effect
1199 vapour pressure
1200 vapour temperature
1201 velocity
1202 vibrational energy

1203 vibrational motion
1204 vinegar
1205 visible
1206 voltage
1207 voltaic cell
1208 volume
1209 volumetric analysis
1210 volumetric flask
1211 washing soda
1212 water
1213 water of crystallization
1214 water of hydration
1216 water softener
1217 water gas
1218 wave function
1219 wave mechanical model
1220 wave particle duality
1221 wavelength
1222 weak acid
1223 weak base
1224 weak electrolyte
1225 weight
1226 word equation
1227 work
1228 X-ray
1229 yield
1230 Z
1231 zeolite
1232 zinc
1233 atomic symbol
1234 isoelectronic
1235 Gay-Lussac's Law
1236 natural gas
1237 heat of vapourization
1238 inspection (balancing)
1239 ratio
1240 heat
1241 room temperature
1242 life
1250 electron configuration
1251 error calculations
1252 Dalton's Theory of the Atom
1253 hydrogen production
1254 Ideal Gas Law
1255 stable electron configuration
1256 equation problems
1257 neutral species
1258 radioactive tracer
1259 reaction mechanism
1260 change in concentration
1261 proton acceptor
1262 proton doner
1263 $K_{eqm}$
1263 $K_{eqm}$
1263 $K_f$
1263 $K_f$
1264 selective precipitation
1265 optical activity
1266 hydrogen ion concentration
1267 hydroxide ion concentration
1268 bond types
1269 electron withdrawing group
1270 Born Haber Cycle
1271 properties of liquids and solids
1273 sulfate
1274 sulfate ion
1275 sulfite
1276 sulfur
1277 sulfuric acid

1278 sulfurous acid
1279 hyposulfurous
1280 hyposulphurous
1281 completion
1282 PV = nRT
1283 calorie
1285 kilopascal
1286 pascal
1287 kPa

# CHAPTER 7

## INSTRUCTIONS FOR USE OF LABORATORY INSTRUMENTS

The laboratory instruments were designed to be used in many diverse ways at the discretion of the teacher.

Some suggestions are:

1) Introduction of new topics
2) Review of topics previously taught
3) Mid-term (Formative Evaluaton) tests
4) End of term (Summative Evaluation) tests

The essential idea is that students be given the opportunity to DESIGN and think about their laboratory work and that teachers teach towards this end.

If the teacher wishes to use any of these instruments for testing purposes it is essential that the students be aware of the testing procedures.

If the students are not familiar with the procedures involved in this type of testing give them a number of practice sessions - working either singly or in pairs - prior to the test day. The students might also be given a printed example of a completed problem. The copies should be collected before the students leave the class.

Two "models" have been developed for the laboratory instruments.

1) <u>PROCEDURAL STEP MODEL</u>

   In this model the student may ask for or be given specific PROCEDURAL STEPS to be used in the laboratory. The student is required to design additional PROCEDURAL STEPS to complete the problem.

2) <u>CLUE MODEL</u>

   This model allows for a greater degree of student inquiry and inventiveness. The student may ask for or be given a series of CLUES which he uses to aid in the design of a laboratory procedure to solve the problem at hand. The CLUES are <u>NOT</u> steps in a laboratory precedure.

The laboratory instruments, both CLUE MODEL and PROCEDURAL STEP MODEL are found in CHAPTER XIV of this pool.

Each of the laboratory problems is written with the same general layout. Each of the instruments consists of a "Student Problem Sheet" and a "Teacher's Guide Sheet". In the outline which follows the problem layout is printed in regular (Titan 10) type and the editorial comments in Gothic 12 type.

## General Outline of Laboratory Instruments

### I INTRODUCTION

In this section the student is introduced to the subject matter to be evaluated. In some of the problems the student will be directed to perform a preliminary experimental operation on which he will be tested in the actual problem.

### II SPECIAL LAB KIT

The hardware, glassware and chemicals specific to this problem are listed. The list may include materials that are not necessary. The teacher must decide whether or not to include those materials to act as distractors. The teacher must also decide if the SPECIAL LAB KIT is to include sufficient materials to answer the problem in a variety of ways or to restrict the problem to only one solution. Materials that are included in the "Standard Laboratory Equipment" are not necessarily listed under the SPECIAL LAB KIT.

### III PROBLEM

Using only the materials in the SPECIAL LAB KIT design an experiment to... The specific problem is outlined in this section; for some problems a few lines may precede the "Using only...experiment to...

The design must be written in detail on the Scoring Guide - Section A - Experimental Design.

Do NOT proceed with the actual experimental work until the teacher has checked and approved the Experimental Design that you have suggested.

NOTE - You are also provided with a kit of Standard Laboratory Glassware and Hardware.

The teacher must check the DESIGN in order to be certain that no unsafe procedures are being attempted. The DESIGN section must also be evaluated (Section A) before the student proceeds to work either with or without any or all of the PROCEDURAL STEPS/CLUES.

IV ALTERNATE SOLUTION(S)

Suggest, if you can, an alternate solution or solutions to the problem you have just completed. The alternate solution(s) may involve the use of any equipment and supplies that you might suggest. The teacher will give you additional mark credit for any workable or reasonable alternative solution(s). Write the alternate solution(s) on the Scoring Guide - Section D - Alternate Solution(s).

Students are encouraged to write an Alternate Solution. This provides an avenue for students who wish to expand the solution they have written, or to supply a solution entirely different from those that the problem designers predicted. The Alternate Solutions(s) may require any form of equipment or supplies - no matter how exotic or sophisticated. Through this section the problems are made as open-ended as possible.

Individual teachers may choose to supply the materials necessary for an Alternate Solution and allow the student to perform the procedures that they have personally designed.

Individual teachers can decide how to use the score assigned to this secton - either as part of the mark out of 25 (a bonus) or to increase the possible total mark to 30 or more.

V TIMING

(1) Time allowed for the complete problem 40 minutes
(2) Time allowed for the "experimental design" 15 minutes

The time allotment given here follows FORMAT A; the times are flexible. Many teachers have increased the time allowed to 50-75 minutes, depending on the length of the class period. Any convenient time distribtution is appropriate. Formats B, C, D and E are described in the GENERAL INSTRUCTIONS TO THE TEACHER. A variety of FORMATS are possible and encouraged.

The 15 minute design and design evaluation period (FORMAT A) is only viable in a very small group - no more than 8 students. For large groups FORMATS B, C, D and E are more convenient and workable.

VI TEST FORMAT

A) PROCEDURAL STEP MODEL

If you do not know how to proceed, you may request a series of five PROCEDURAL STEPS from the teacher.. The PROCEDURAL STEPS are arranged in a sequential order. The teacher, after examining your progress, will give you the appropriate

STEP(S). Each STEP will bring you closer to a complete procedure necessary to solve the problem. You may request any or all of the PROCEDURAL STEPS associated with this problem. Each STEP that you request will result in a lower possible score that you can obtain.

Students are advised to ask for PROCEDURAL STEPS as soon as they think that they are "stuck". There is ample opportunity provided to recover Design marks.

After 15 minutes the students' designs will be collected and evaluated. Students will be given complete procedures to follow unless they have presented procedures which have been evaluated as complete and workable.

Only in FORMATS A and B may students request the "next" procedural step while designing the experiment. Procedures must be complete before laboratory work is started. In FORMATS C, D and E the students are given all the procedural steps they require during evaluation of the Design. In each case the teacher decides which procedural step(s) to give to each of the student.

B) CLUE MODEL

If you do not know how to proceed you may request a series of CLUES from the teacher. The CLUES are arranged in a sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you request will result in a lower possible score that you can obtain.

You may request any, or all of the CLUES associated with this problem. The CLUES will be given to you, one at a time, in a specified order. There are ___ CLUES for this problem (in addition to the Procedural Clue). The Procedural Clue (Clue No___) will give you an entire laboratory procedure to follow. If you request this CLUE you will not receive any of the nine (9) marks reserved for the CLUES. It is advisable that you take some of the earlier CLUES before you request the Procedural Clue.

After 15 minutes the student will be given a CLUE if the Design presented by the student is not sufficient to allow the student to start performing laboratory work.

Only in FORMATS A and B may students request the CLUES while designing the experiment. Procedures must be approved before laboratory work is started. In FORMATS C, D and E the students are given all the CLUES they require during evaluation of the Design. In each case the teacher decides which CLUES to give the student.

The teacher may suggest that laboratory work be started before the procedure is complete. A student may develop further steps in the procedure after making some initial observations.

In both the CLUE MODEL and the PROCEDURAL STEP MODEL the students exhibit inertia towards accepting assistance. They must, by experience, learn that some marks must be sacrificed in order to conserve time. This stage in the learning process is a difficult, but important stage for the students to internalize.

## VII EVALUATION SCHEME

NOTE: (1) You are permitted to use the Handbook of Chemistry and Physics (Chemical Rubber Publishing Co.) as well as your textbook.

(2) You must leave ALL your "rough work" with the teacher.

The Handbook of Chemistry and Physics is not available in all schools. Some teachers prefer a data book or a data sheet which may be provided to the students. Any variation is acceptable. The idea here is to teach students to use reference materials such as the Handbook. Individual teachers may elect to allow students to take notebooks into the test. The option is open.

A useful and inexpensive alternative to the Handbook of Chemistry and Physics is:
Handy Chemical Data for Student (SI Metric)
(The Science Teachers' Association of Ontario #79004)

### A) PROCEDURAL STEP MODEL

(Total possible score......25)

| DESIGN (15 marks) | | | PERFORMANCE (10 marks) |
|---|---|---|---|
| Phase I (3 marks per step) | Procedural Steps Required | Phase II (2 marks per step) | The awarding of performance marks will vary with each problem. |
| 1. ____ | 1. ____ | 1. ____ | |
| 2. ____ | 2. ____ | 2. ____ | |
| 3. ____ | 3. ____ | 3. ____ | |
| 4. ____ | 4. ____ | 4. ____ | |
| 5. ____ | 5. ____ | 5. ____ | |

Each of the five PROCEDURAL STEPS is assigned 3 marks during Phase I of the DESIGN period.

After the initial evaluation the student is given the <u>next</u> procedural step - this step will depend on the student's progress.

In Phase II of the DESIGN period the student is awarded 2 marks for each additional procedural step that he designs.

A very simple matrix can be developed to illustrate the mark assignment - see page 83.

The student need only design one of the procedural steps (in Phase I) in order to be eligible to score 13/25 on any problem.

B) CLUE MODEL (Total possible score....25)

| DESIGN (5 marks) | | CLUES (9 marks) | | PERFORMANCE (11 marks) |
|---|---|---|---|---|
| NONE | 0 | No. 1 ___ | 2 | The awarding of performance marks will vary with each problem. |
| FAULTY (requires an initial clue) | 2 | No. 2 ___ | 1 | |
| | | No. 3 ___ | 2 | |
| FAULTY (does not require an initial clue) | 3 | . | . | |
| | | . | . | |
| GOOD AND WORKABLE | 5 | . | . | |
| | | No. n-1 | | |
| | | No. n ___ | 9 | |

Each of the n-1 CLUES is assigned a number of marks which total to 8. The CLUES are not necessarily of equal value. The nth clue (the Procedural Clue) is assigned a value of 9 marks.

The student can obtain a score of 13/25 if he makes any attempt at an initial Design - however faulty.

In both the PROCEDURAL STEP MODEL and the CLUE MODEL the student can score 13/25 if he does minimal design and then follows a given procedure accurately and carefully.

SECTIONS VIII, IX AND X ARE FOR TEACHER USE ONLY

## VIII PROCEDURAL STEPS/CLUES

A teacher must be present in the laboratory whenever there are any students working. The teacher must be available to provide CLUES/PROCEDURAL STEPS to the students so that time is not wasted.

The delivery of CLUES/PROCEDURAL STEPS is different, depending on the format being used. The formats differ in the time allowed for design. The formats are described beginning on page 72.

A) PROCEDURAL STEPS

The procedure for each problem is divided into five approximately equal parts. The steps are clearly stated procedural directions for the student to follow. After receiving a step or steps, the student (Formats A and B) may continue to design the remainder of the experimental procedure. The procedural steps are provided for the teacher to duplicate, cut up and distribute as necessary. The teacher should plan to retrieve all of the steps by stapling them to the student's Scoring Guide as the steps are distributed.

B) CLUES

For each problem there are a number of CLUES, including the last CLUE - the Procedural Clue. The clues are hints which may assist the student to complete an experimental design. After receiving a clue or clues, the student (Formats A and B) may continue to design additional stages in the experimental procedure. The clues are provided for the teacher to duplicate, cut and distribute as necessary. The teacher should plan to retrieve all of the CLUES by stapling them to the student's Scoring Guide as the CLUES are distributed.

IX SUGGESTED PROCEDURE

There are many procedures for solving each of the problems. The set of CLUES/PROCEDURAL STEPS is designed to lead the students to the procedure outlined in the TEACHER'S GUIDE section VIII. The teacher is responsible for approving and supplying the materials for any different procedure(s) that may be suggested. The teacher has the option to allow marks under the category of "Additional Solution(s)" for procedures other than "The Suggested Procedure".

There may be many procedures for solving each of the problems. The outline in this section is only one possible procedure that students might suggest. The teacher is responsible for approving any procedure(s) that might be suggested.

In most cases only one solution has been provided. The solution is outlined in detail with the five procedural step divisions indicated. This complete outline also corresponds to the Procedural Clue. Teachers are encouraged to outline additional procedures in this section as they and their students devise new methods of solving the problem in question.

X SPECIFIC LABORATORY AND SECURITY PROCEDURES

The items listed in this section are in addition to the Standard Laboratory and Security Procedures that are in effect for all of the problems. In this section the teacher is also provided with data, recipes and suggestions for use with each of the specific problems.

SCORING GUIDE

The following two sheets (both sides) are samples of the PROCEDURAL STEP MODEL and CLUE MODEL SCORING GUIDES for a typical problem. All of the evaluation information required by the teacher is included on the two sides of the sheet.

## STANDARD LABORATORY AND SECURITY ARRANGEMENTS

1. Provide sufficient test tubes, glassware and distilled water so that students can use and rinse equipment readily.

2. Provide all standard laboratory apparatus such as beakers, clamps, burners, tongs, etc.

3. Make safety glasses available and mandatory for those students who do not ordinarily wear eye glasses.

4. Please collect ALL materials with which each student was working - both written as well as chemical.

5. Do not allow the students to take any "rough notes" out of the laboratory.

6. Space the students in the laboratory to ensure individual work.

7. Make a copy of "The Handbook of Chemistry and Physics" available to the students.

8. Make copies of the Periodic Table available to the students.

9. Ask student NOT to write on the question papers.

10. Be sure to collect all copies of the CLUES/PROCEDURAL STEPS.

11. Make sure that students return items to the SPECIAL LAB KIT.

12. Label the trays containing UNKNOWNS so that you can cross-reference the Tray Number and the Unknown Codes.

13. For problems in which unknowns are used the coding system must be varied regularly in order to ensure individual student work. The individual teachers will assign the appropriate code letters to the unknowns.

## STANDARD LABORATORY EQUIPMENT

All of the materials in the following list may not be necessary for all of the laboratory problems. Teachers may substitute or omit some of the items. The list is provided to allow students to select some materials at their own option.

These materials are to be provided in addition to the SPECIAL LAB KIT. Some of the materials in this list may also appear in the SPECIAL LAB KIT for individual problems.

1. Test tubes (variety of sizes)
2. Glass plates or spot plates (black, white and clear)
3. Beakers (50, 100, 250, 400 and 600 mL)
4. Flasks (Erlenmeyer - 250 mL)
5. Funnels
6. Evaporating dishes
7. Eye droppers
8. Pipets
9. Stirring rods
10. Clamps - test tube and ring
11. Bunsen burner
12. Gauze mat
13. Matches
14. Glass cutting files
15. Glass tubing
16. Tongs
17. Rubber stoppers - variety of sizes
18. Buret
19. Balance (centigram)
20. Stop watch (if available)
21. Crucibles and covers
22. Thermometer (-10 to 110 degrees $^{o}C$)
23. Filter paper
24. Wood splints
25. Litmus paper (red and blue)
26. Distilled water (in dispenser bottle)
27. Delivery tubes
28. Graduated cylinders (10, 25, 50, 100 and 250 mL)
29. Gas collecting bottles
30. Cover glasses
31. Support stand
32. Wax pencil

NOTE
1. Additional materials may be specified for individual problems - some will be supplied along with the printed materials.
2. If any of these materials are not available, individual teachers may choose to make substitutions or additions.

GENERAL INSTRUCTIONS - TO THE TEACHER

FORMAT A

Students are presented with a problem and allowed one class period to complete the problem. The first 15 minutes of the period are assigned to EXPERIMENTAL DESIGN; the remainder of the period is used for actual experimental work. The time distribution can be varied by individual teachers.

SPECIAL CONSIDERATIONS - FORMAT A

1. There should be no more that 8 students in the laboratory. This will allow the teacher the opportunity to move about the laboratory and supervise all the students.

2. Ideally the students should not be working on the same problem.

3. The problems should be distributed around the laboratory.

4. During the initial 15 minute Design Period the teacher must evaluate all the student designs.

5. CLUES/PROCEDURAL STEPS are given to students who request the CLUES/PROCEDURAL STEPS as well as (at the discretion of the teacher) to those students who appear to be "stuck".

6. At the end of the Design Period (15 minutes) the students must be given those CLUES/PROCEDURAL STEPS necessary to complete their procedures.

7. Students must write their suggested procedure in detail on the Scoring Guide.

8. Marks are entered on the Scoring Guide while the students are working.

NOTE: i) The 15 minute DESIGN Period is rushed; the teacher may find it difficult to evaluate all 8 Designs during the 15 minute period.

ii) The restriction to a maximum of 8 students at a time is flexible. The number can be maximized by making use of time before and after classes, lunch hours and free periods.

iii) For evaluation use the laboratory instruments can be administered during the regular examination timetable. Students can "sign up" for specific time periods.

FORMAT B

Students are presented with a problem and allowed two class periods, or parts thereof, to complete the problem. The teacher must decide how much time should be devoted to each aspect of the problem.

On day 1 the students may be given between 15 minutes and the full period (at the discretion of the individual teacher) to complete the EXPERIMENTAL DESIGN. During this time the teacher may be asked for CLUES/PROCEDURAL STEPS by individual students. The teacher should not offer CLUES/PROCEDURAL STEPS to student(s) unless called upon by the student(s).

At the end of the Design Period the Scoring Guides, problems and SPECIAL LAB KITS are collected from each student.

SPECIAL CONSIDERATIONS - FORMAT B

1. All students can work at the same time.
2. All students can work on the same problem, or on one of two different problems. Students sitting at the same lab bench should be given different problems.
3. The teacher is not obligated to evaluate a large number of Designs in a short period of time.
4. The EXPERIMENTAL DESIGNS are evaluated by the teacher after the class period.
5. CLUES/PROCEDURAL STEPS are stapled to the students' Scoring Guides. Since the students are free to discuss the problem with classmates, and others, it is not possible to continue the Design feature of the test on the second day. Each student should be given all the CLUES/PROCEDURAL STEPS necessary in order to complete his design. Students are encouraged to perform the experiment which they designed.
6. Indicate on the Scoring Guide those CLUES/PROCEDURAL STEPS that were necessary for the student to complete the problem. In the case of the CLUE MODEL the teacher will have to decide whether or not a particular student actually required the Procedural Clue.
7. The second day becomes a lab day - all students should work independently.
8. The unknowns must be coded - and coded differently for each student. This will prevent copying of data.
9. In those cases where there are a variety of unknowns available, code and spread the different unknowns around the laboratory.

NOTE:

i) Any out-of-school discussion will not change the DESIGN marks. The DESIGNS are evaluated on work done in class on day 1. The out-of-school discussions can only be advantageous.

ii) Additional CLUES or PROCEDURAL STEPS may be necessary for some students on day 2.

FORMAT C

FORMAT C is identical to FORMAT B in all but one respect. The teacher evaluates each student's procedure, then provides each member of the class with a complete procedure to follow. All students perform the same experiment. In essence, day 1 is a Design period and day 2 is a laboratory period. At the teacher's discretion, depending on the length of time of available, both the Design and the laboratory work can be done in the same class period.

SPECIAL CONSIDERATIONS - FORMAT C

1. PROCEDURAL STEPS/CLUES that the student required should be stapled to the student's DESIGN so that he knows how well he did on the DESIGN part of the evaluation.

2. The teacher only has to prepare materials for one laboratory procedure. Considerable time is saved for the teacher by using FORMAT C.

3. It is possible that some students may feel "cheated" by not performing the experiment they designed.

4. The students must know, beforehand, what general format the test will follow. They should not be surprised that they will all perform the same experiment.

FORMAT D

FORMAT D is identical to FORMAT B in all except one respect. No CLUES/ PROCEDURAL STEPS are distributed during the Design Period. At the end of the Design Period all materials are collected by the teacher.

SPECIAL CONSIDERATIONS - FORMAT D

1. The problems are used in a two day format. Day 1 is a Design Period. Day 2 is a laboratory period.

2. Laboratory Designs are evaluated out of class by the teacher.

3. The teacher staples to the students' Scoring Guide the CLUES/PROCEDURAL STEPS necessary to complete the experimental procedure. In the case of the CLUE MODEL the teacher will have to decide whether or not a particular student actually required the Procedural Clue.

4. On the second day each student performs the experiment he has designed, or the experiment that he was given if the student design was not workable.

FORMAT E

FORMAT E is identical to FORMAT C in all except one respect. No CLUES/PROCEDURAL STEPS are distributed during the Design Period. At the end of the Design Period all materials are collected by the teacher.

SPECIAL CONSIDERATIONS - FORMAT E

1. The problems are used in a two day format. Day 1 is a Design Period. Day 2 is a laboratory period.

2. Laboratory Designs are evaluated out of class by the teacher.

3. The teacher staples to the student's Scoring Guide the CLUES/ PROCEDURAL STEPS necessary to complete the experimental procedure. In the case of the CLUE MODEL the teacher will have to decide whether or not a particular student actually required the Procedural Clue.

4. On the second day the teacher distributes the same experimental procedure to all the students. The students all perform the same experiment - the experiment outlined in the procedural clue.

5. The teacher may decide to complete the whole exercise in one class period. After collecting the student designs, distribute the experiment outline to the students.

GENERAL INSTRUCTIONS TO THE STUDENT

FORMAT A

1. Do NOT start any experimental work until approval is received from the teacher.

   No Experimental work is to be done until your Experimental Design is complete and approved by the teacher.

2. All Experimental Designs MUST be written in detail in Section A of the Scoring Guide. Call the teacher to your work area when you have completed your initial Laboratory Design. The procedure must include outlines of all the calculations (if necessary) that will be performed.

3. There are some problems for which some special experimental work is done prior to the Experimental Design. The instructions for the problem will indicate this clearly. The teacher will tell you which experiment(s) to perform.

4. Do NOT taste any materials - some may be poisonous.

5. For each problem you may be provided with a data sheet as well as all the necessary equipment and supplies. For each problem there is a SPECIAL LAB KIT in addition to a kit of Standard Laboratory apparatus.

6. You are permitted to use the Handbook of Chemistry and Physics as well as your textbook and any materials provided by the teacher.

7. Each problem is assigned an initial 15 minute Design Period. Following that time period the teacher will evaluate your progress and give you the PROCEDURAL STEPS/CLUES necessary to complete the procedure that you have designed.

8. You will get significant credit for any design that you produce during the initial Design Period. There are many possible correct designs for each problem.

9. The category titled "Alternate Solution(s)" will enable you to suggest solutions that were not provided for in the SPECIAL LAB KIT. You will receive additional credit for these solutions. There may be many alternate solutions for each problem.

10. Remember that these materials have been used by other people. Rinse all glassware and transferring equipment with distilled water before you use the equipment.

11. You may NOT remove any written, printed or laboratory materials from the laboratory.

12. Please replace the SPECIAL LAB KIT in the form in which you found it.

A) PROCEDURAL STEP MODEL

Do NOT waste time - if you do not know how to proceed - ask for a PROCEDURAL STEP. You may request a series of PROCEDURAL STEPS from the teacher. The PROCEDURAL STEPS are arranged in sequential order. The teacher - after examining your progress will give you the appropriate PROCEDURAL STEP(S). Each PROCEDURAL STEP that you are given will result in a lower possible score that you may achieve. Fifteen (15) marks out of 25 are reserved for PROCEDURAL STEPS. It is advisable that you request a PROCEDURAL STEP as soon as you are "stuck". This will avoid waste of time during the Design Period.

Ten (10) marks out of the 25 marks are reserved for performance of the experiment and a correct solution to the problem. Even if your require four of the five PROCEDURAL STEPS you can still score 13/25 on each of the problems.

B) CLUE MODEL

Do NOT waste time - if you do not know how to proceed - ask for a CLUE. You may request a series of CLUES from the teacher. The CLUES are arranged in sequential order. The teacher - after examining your progress will give you the appropriate CLUE(S). Each CLUE that you are given will result in a lower possible score that you may achieve. Nine (9) marks out of 25 are reserved for CLUES. The final CLUE for each problem (Procedural Clue) outlines one possible procedure for the solution to the problem. The use of this final CLUE will result in the loss of all nine (9) marks reserved for the CLUES. It is always advisable that you take some of the earlier CLUES before requesting the Procedural Clue for any problem. It is advisable that you request a CLUE as soon as you are stuck. This will avoid waste of time during the Design Period.

Eleven (11) marks out of the 25 marks are reserved for performance of the experiment and a correct solution to the problem. Even if you require all the CLUES, following an initial design attempt, you can still score 13/25 on each of the problems.

FORMAT B

FORMAT B is similar to FORMAT A, with the following exceptions.

1. The problem assigned to you must be completed in two stages - on separate days.

2. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given.

FORMAT C

FORMAT C is similar to FORMAT A and FORMAT B, with the following exceptions.

1. The problem assigned to you must be completed in two stages - on separate days, or if indicated by the teacher,on the same day.

2. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given. All students will perform the same experiment.

FORMAT D

FORMAT D is similar to FORMAT B, with one major exception.

You will NOT receive any PROCEDURAL STEPS/CLUES on day 1 during the Design Period.

1. The problem assigned to you must be completed in two stages - on separate days.

2. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given.

3. On the second day the teacher will return your Scoring Guide and will allow you to perform the experiment that you designed, or the experiment outlined in the PROCEDURAL STEPS/CLUES that are stapled to your Scoring Guide.

FORMAT E

FORMAT E is similar to FORMAT C with one major exception.

1. You will NOT receive any PROCEDURAL STEPS/CLUES during the Design Period.

2. The problem assigned to you must be completed in two stages - on separate days.

3. On the first day you will be given the problem and will have a specified time period to design a laboratory solution to the problem. On the second day you will use your method (corrected by the teacher, if necessary) to actually determine an answer to the problem you were given.

4. On the second day the teacher will return your Scoring Guide and will allow you to perform the experiment that you designed, or the experiment outlined in the PROCEDURAL STEPS/CLUES that are stapled to your Scoring Guide.

Summary of FORMATS A, B, C, D and E.

TO THE TEACHER

FORMAT A

One full class period is required. The period may be 35 to 70 minutes in length.

The Design and the Laboratory work are done in the same period. The Design work is done in the first 15 to 30 minutes and the Laboratory work in the remaining 25 to 55 minutes. The length and distribution of time is at the discretion of the teacher.

The small number (6 - 10) of students allows for student - teacher interactions. The students can recover Design marks after receiving one or more PROCEDURAL STEPS/CLUES.

FORMAT B

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 - 30 minutes). Laboratory work is done on Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is more limited because the larger number (full class) of students limits the student - teacher interactions during the Design Period. Students perform their own Experiment on Day 2.

FORMAT C

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 - 30 minutes). Laboratory work is done on Day 1 or Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is more limited because the larger number (full class) of students limits the student - teacher interactions during the Design Period. Students all perform the same experiment, designed by the teacher, on Day 1 or Day 2.

FORMAT D

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 - 30 minutes). Laboratory work is done on Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is NOT available. No PROCEDURAL STEPS/CLUES are distributed during the Design Period. All evaluation is carried out after the Design Period is concluded. Students perform their own experiments on Day 2.

FORMAT E

Parts of two class periods are required. Design is done on Day 1, at the end of the period (15 -30 minutes). Laboratory work is done on Day 1 or Day 2 (25 - 70 minutes).

The opportunity for recovery of Design marks is NOT available.

No PROCEDURAL STEPS/CLUES are distributed during the Design Period.

All evaluation is carried out after the Design Period is concluded.

Students all perform the same experiment, designed by the teacher on Day 1 or Day 2.

EVALUATION PATTERN

PROCEDURAL STEP MODEL
FORMAT A,B,C

EXPERIMENTAL DESIGN (Maximum 15 Marks)

(a) The student is assigned marks (to a maximum of 15 marks) for each of the PROCEDURAL STEPS that are designed correctly.
(b) The student is awarded 3 marks for each of the PROCEDURAL STEPS that are designed correctly, prior to the initial, Phase I evaluation of the Experimental Design by the teacher.
(c) The student is awarded 2 marks for each of the PROCEDURAL STEPS that are designed correctly, after the initial, Phase II evaluation of the Experimental Design by the teacher.
(d) There are NO penalties assessed for requesting and receiving one or more PROCEDURAL STEPS.

ASSIGNMENT OF MARKS

During the Initial Design Period (Phase I) the student may design any or all of the PROCEDURAL STEPS ($P_1$, $P_2$, $P_3$, $P_4$ and $P_5$) corectly. The student is awarded 3 marks for each of the STEPS designed correctly.

The PATTERN of marks awarded for correct Design is outlined in the following sections.

1) Complete Design (Phase I)
   5/5 All five STEPS are designed correctly during the Initial Design Period. 15

2) Incomplete Design (Phase I)
   4/5 Four of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_5$. 12

3) Incomplete Design (Phase I)
   3/5 Three of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_4$.

   (i) The student designs $P_5$ correctly 11

   (ii) The student is given $P_5$. 9

4) Incomplete Design (Phase I)

   2/5 Two of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_3$.

   (i) The student designs $P_4$ and $P_5$ correctly. 10

   (ii) The student designs 1 of $P_4$ and $P_5$ correctly and is given the remaining PROCEDURAL STEP. 8

   (iii) The student is given $P_4$ and $P_5$. 6

5) Incomplete Design (Phase I)

1/5 One of the five STEPS is designed correctly during the Initial Design Period. The student is given $P_2$.

| | | |
|---|---|---|
| (i) | The student designs $P_3$, $P_4$ and $P_5$ correctly. | 9 |
| (ii) | The student designs 2 of $P_3$, $P_4$ and $P_5$ correctly and is given the remaining PROCEDURAL STEP. | 7 |
| (iii) | The student designs 1 of $P_3$, $P_4$ and $P_5$ correctly and is given the two remaining PROCEDURAL STEPS. | 5 |
| (iv) | The student is given $P_3$, $P_4$ and $P_5$. | 3 |

6) Incomplete Design (Phase I)

0/5 None of the five STEPS are designed correctly during the Initial Design Period. The student is given $P_1$.

| | | |
|---|---|---|
| (i) | The student designs $P_2$, $P_3$, $P_4$ and $P_5$ correctly. | 8 |
| (ii) | The student designs 3 of $P_2$, $P_3$, $P_4$ and $P_5$ correctly and is given the remaining PROCEDURAL STEP. | 6 |
| (iii) | The student designs 2 of $P_2$, $P_3$, $P_4$ and $P_5$ correctly and is given the two remaining PROCEDURAL STEPS. | 4 |
| (iv) | The student designs 1 of $P_2$, $P_3$, $P_4$ and $P_5$ correctly and is given the three remaining PROCEDURAL STEPS. | 2 |
| (v) | The student is given $P_2$, $P_3$, $P_4$ and $P_5$. | 0 |

PERFORMANCE (Maximum 10 marks)

The various STEPS in the procedure, calculations and the answer to each problem will be assigned credit that total 10 marks. The student may obtain all or any of these 10 marks regardless of the number of PROCEDURAL STEPS given to the student.

Examination of the EVALUATION PATTERN indicates that in order to achieve a score of 13/25 the student must produce some of the Experimental Design.

EVALUATON PATTERN

PROCEDURAL STEP MODEL
FORMAT D, E.

EXPERIMENTAL DESIGN (Maximum 15 marks)

(a) The student is assigned marks (to a maximum of 15) for each of the PROCEDURAL STEPS that are designed correctly.

(b) The student is awarded 3 marks for each of the PROCEDURAL STEPS that are designed prior to evaluation of the Experimental Design by the teacher (Phase I).

(c) There are NO penalties assessed for requesting and receiving one or more PROCEDURAL STEPS.

ASSIGNMENT OF MARKS

During the Design period the student may design any or all of the PROCEDURAL STEPS ($P_1$, $P_2$, $P_3$, $P_4$ and $P_5$) correctly. The student is awarded 3 marks for each of the PROCEDURAL STEPS designed correctly.

PERFORMANCE (Maximum of 10 marks)

The various steps in the calculations and the answer to each problem will be assigned credit that total 10 marks. The student may obtain all or any of these 10 marks regardless of the number of PROCEDURAL STEPS given to the student.

Examination of the EVALUATION PATTERN indicates that in order to achieve a score of 13/25 the student must produce some of the Experimental Design.

## MATRIX OF MARKS

| | PHASE I INITIAL DESIGN No. Of STEPS | MARKS | No. of "FREE" STEPS GIVEN | PHASE II ADDITIONAL DESIGN No. of STEPS | MARKS | TOTAL MARKS |
|---|---|---|---|---|---|---|
| COMPLETE | | | | | | |
| 1) | 5 | 15 | 0 | 0 | 0 | 15 |
| INCOMPLETE | | | | | | |
| 2) | 4 | 12 | 1 | 0 | 0 | 12 |
| 3) (i) | 3 | 9 | 1 | 1 | 2 | 11 |
| (ii) | 3 | 9 | 2 | 0 | 0 | 9 |
| 4) (i) | 2 | 6 | 1 | 2 | 4 | 10 |
| (ii) | 2 | 6 | 2 | 1 | 2 | 8 |
| (iii) | 2 | 6 | 3 | 0 | 0 | 6 |
| 5) (i) | 1 | 3 | 1 | 3 | 6 | 9 |
| (ii) | 1 | 3 | 2 | 2 | 4 | 7 |
| (iii) | 1 | 3 | 3 | 1 | 2 | 5 |
| (iv) | 1 | 3 | 4 | 0 | 0 | 3 |
| 6) (i) | 0 | 0 | 1 | 4 | 8 | 8 |
| (ii) | 0 | 0 | 2 | 3 | 6 | 6 |
| (iii) | 0 | 0 | 3 | 2 | 4 | 4 |
| (iv) | 0 | 0 | 4 | 1 | 2 | 2 |
| (v) | 0 | 0 | 5 | 0 | 0 | 0 |

EVALUATION PATTERN
CLUE MODEL
FORMAT A,B,C

1. <u>EXPERIMENTAL DESIGN (Maximum 5 marks)</u>

(a) The student does not prepare any laboratory design
material within the Design Period. 0

(b) The student prepares a "faulty" laboratory design
which in the opinion of the examiner does not
5 contain a laboratory entry point. The student 2
requires an "initial" CLUE prior to starting any
laboratory work.

(c) The student prepares an incomplete laboratory design
but does not need required an "initial" CLUE in order to 3
start the laboratory work.

(d) The student prepares a good and workable laboratory
design. 5

2. <u>CLUES (maximum of 9 marks)</u>

The student will gain nine (9) marks if the student does not
require any of the CLUES associated with the assigned
problem. If the student requires the final CLUE
9 (Procedural Clue) he will NOT be awarded any of the
nine (9) marks associated with the CLUES. It is advisable
that the student take some of the earlier CLUES before
requesting the Procedural Clue.

3. <u>PERFORMANCE (Maximum 11 marks)</u>

The various steps in the procedure, calculations and the
answer to each problem are assigned marks that total 11
marks. The student may obtain all or any of these 11
marks regardless of the number of CLUES required.

11 Examination of the EVALUATION PATTERN indicates that any
student may obtain 13 marks out of the total possible score
25 of 25 marks even if he requires all the available CLUES.
(TOTAL) It is only necessary that the student attempt to prepare a
laboratory design in order to be able to obtain a score of
13/25 on each of the problems.

CLUE MODEL FORMAT D, E.

The evaluation of sections:

I - Experimental Design (maximum 5 marks)

and III - Performance (maximum 11 marks)

are indentical to the evaluation pattern described for Formats A, B, and C.

II - CLUES (maximum 9 marks)

This section is evaluated in the same way as for Formats B and C, but the students are NOT given any clues during the Design Period. As a result of reading the Design, the teacher must decide which clues might have been given to each of the students.

In most cases, if the Design is not complete, the students will be judged to have required the Procedural Clue.

# CHAPTER 8

## DIAGNOSTIC INSTRUMENTS

The set of diagnostic instruments is specifically designed to help teachers discover how students think about certain common and serious misconceptions in Chemistry. The instruments are intended to permit identification of special individual difficulties and to lead to such remedial steps as seem appropriate. These types of questions sometimes shed light on otherwise puzzling cases of student misunderstanding or apparent inability to do the work. (Other instruments in the pool may also be used to serve a diagnostic function.)

This set of instruments deals with three topics:

1. <u>Conservation of Mass</u>
   Conservation of mass in physical and chemical changes in closed systems. (5 instruments)
2. <u>Solutions</u>
   Distinguishing between the amount of solute present and the concentration of a solution. (2 instruments)
3. <u>Equilibrium</u>
   Distinguishing between the rate of reaction and the yield in equilibrium. (5 instruments)

Each question is given in the form used for class try-out except where minor editing was required. An @ beside the item signals an edited item. Below the instrument itself is a table of numbers of students responding in several categories plus a small number of typical prose responses quoted directly from the field screening.

Users should note that it is important to register both the students choice <u>and</u> the reason given for it. It is entirely possible to make the "correct" choice for a reason that reveals important misconceptions. It is equally possible to make the wrong choice and reveal full understanding of the phenomenon when stating the reason. The teacher as diagnostician will attend more to the reasons for the answer than to the actual answer because the reason reveals the state of the student's understanding.

CONSERVATION OF MASS No. 1

The mass of a tightly sealed flask containing an ice cube is 358 g. If the mass is measured again after the ice has melted it will be:
(check one)

increased ☐

@ decreased ☐

the same ☐

Give the reason for your answer. ______________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| increased | 1 | 15 |
| decreased | 0 | 19 |
| the same | 156 | 10 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"While undergoing a change in physical state, the number of particles, thus mass, will not change."
"Nothing can get in or out so mass can't change."
"The amount of material in the flask has not changed."
"Law of Conservation of Mass."

Correct Choice, Incorrect Concept:

"The pressure will always be constant because the flask is sealed and therefore the volume is the same."
"The Law of Definite Composition."
"Because in doing experiments in class we used the same weight measurements in formulas for ice after the ice had melted."

Incorrect Choice, Correct Concept:

"Because some of the moisture in the air attaches around outer face of the cold flask."

Incorrect Choice, Incorrect Concept:

"When water freezes, more air particles are trapped in ice than in water."
"Solid is more dense, therefore more volume, therefore heavier."
"The mass of water decreases as it goes from solid to liquid form."
"A liquid is heavier than itself when frozen."
"The energy the block absorbs increases the mass."

CONSERVATION OF MASS No. 2

A sealed flask containing sugar and water is found to have a mass of 471 g. The flask is gently shaken until all the sugar dissolves. When the mass is determined again it will be:
(check one)

increased ☐

@ decreased ☐

the same ☐

Give the reason for your answer. ____________________

____________________

____________________

____________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| increased | 6 | 1 |
| decreased | 11 | 0 |
| the same | 5 | 77 |

TYPICAL REASONS

Correct Choice, Correct Concept:
"The substance dissolves, but it is still there."
"No matter has been added or subtracted."
"The Law of Conservation of Mass."

Correct Choice, Incorrect Concept:
"Law of Definite Proportions."
"The water absorbs the sugar."

Incorrect Choice, Correct Concept:
"The reason is that even though the sugar is dissolved it will add to the mass of the flask."

Incorrect Choice, Incorrect Concept:
"Because the sugar absorbs the water and makes the sugar crystals heavier."
"Because the sugar dissolves in the water and has less matter."

CONSERVATION OF MASS No. 3

White crystals of barium nitrate are placed in an open test tube and heated in a fume hood. The crystals melt and the liquid starts to bubble, gently at first. Then it begins to turn yellow, boils strongly and gives off brown fumes. When cooled, the liquid becomes a white solid again.

If the tube and crystals had a mass of 103 g before heating, what would the mass be after heating and cooling?

(check one)

more than 103 g ☐

@ less than 103 g ☐

the same as 103 g ☐

Give the reason for your choice. ______________________

______________________________________________________

______________________________________________________

______________________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| more | 1 | 1 |
| less | 59 | 5 |
| same | 2 | 5 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"The molecules lost in the chemical reactions are not replaced, therefore the system has less mass."

"Water content decreases."

"If some of the gas leaves, it will weigh less when cooled."

"Mass was lost in the brown fumes."

Correct Choice, Incorrect Concept:

"If fumes are given off something must have been burned."

Incorrect Choice, Correct Concept:

"The solution first loses its gas and then must regain it from the air because the crystals are back to the same colour when cooled. So in fact it didn't lose any material (only temporarily)."

Incorrect Choice, Incorrect Concept:

"The mass should stay the same because only the state of the crystals change. There was only oxidation taking place."

"Because some oxygen will mix with the barium."

CONSERVATION OF MASS No. 4

A flask is quarter-filled with dilute sulfuric acid. A small test tube containing barium chloride solution in water is placed upright in the flask. A stopper is set very tightly in the flask mouth. The mass of the entire apparatus is 339 g. The flask is tilted enabling the two solutions to mix. A thick white solid material (barium sulfate) forms. The mass of the apparatus will now be: (check one)

greater ☐

@ smaller ☐

the same ☐

Give the reason for your choice. ______________________

______________________________________________

______________________________________________

______________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| greater | 0 | 19 |
| smaller | 0 | 6 |
| the same | 64 | 9 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"Mass of the reactants equals the mass of the 'stuff' after reaction (Law of Conservation of Mass)."

"There is still the same amount of everything, therefore the mass would be the same."

"The mass can't change because nothing was added or subtracted from the total mass."

Correct Choice, Incorrect Concept:

"Any energy given off in the reaction will stay in the tube and the mass stays the same."

"Depends on the Law of Definite Composition."

"Because a catalyst was added and it will weigh the same."

Incorrect Choice, Correct Concept: NIL

Incorrect Choice, Incorrect Concept:

"The two substances have formed a new substance which will have a different mass."

"Because a solid was formed."

"A new substance has been made along with the contents already in the flask."

CONSERVATION OF MASS No. 5

A flask is quarter-filled with a very dilute acid. A small test tube containing 3 marble chips is placed upright in the flask. A stopper is set very tightly in the flask mouth. The mass of the entire apparatus is 328 g. Now the flask is tilted causing the marble chips to fall into the acid. A gas is seen to bubble up from the chips and they grow smaller in size. If the the mass of the apparatus is measured the result will be: (check one)

greater ☐

@ less ☐

the same ☐

Give the reason for your choice. ____________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| greater | 0 | 5 |
| less | 5 | 30 |
| the same | 82 | 11 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"Nothing has left the flask therefore the mass of the apparatus will be the same."

"Mass remains constant in a closed system."

"It's the same amount only in a different form."

Correct Choice, Incorrect Concept:

"The gas doesn't weigh anything so the mass will be the same."

"Acid ate the marble chips."

"If it bubbles it means it's giving off a gas."

Incorrect Choice, Correct Concept:

"If there is a gas forming inside, there will be a significant amount of bouancy resulting making the weight less."

Incorrect Choice, Incorrect Concept:

"When molecules are rearranged, they can either increase or decrease their mass."

"Gas has formed, therefore mass has decreased."

"More, because gas will help in the weight."

"Because the mass of a gas is less than the mass of a liquid."

"Some of the matter will have changed to energy in the form of heat and will lower the mass."

SOLUTION No. 1

A solution of salt (sodium chloride) in water is divided into two exactly equal portions, A and B. A is left alone, B has distilled water added. Which statement is true?
(check one)

A will taste saltier than B ☐

A will taste less salty than B ☐

A and B will taste equally salty ☐

Give the reason for your choice. ______________________

________________________________________________

________________________________________________

________________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| A saltier | 138 | 26 |
| A less salty | 3 | 11 |
| Equally salty | 1 | 23 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"There will be a higher proportion of salt particles for water particles in A than in B."

"There is more water in B so it will thin out the salt (less concentrated)."

"There is more salt per volume of liquid in A than in B."

"B will have the same amount of salt as A but it will have a larger solution."

Correct Choice, Incorrect Concept:

"The minerals have been removed from B changing the taste."

"Distilled water would have less salt than normal water, therefore A would have a greater sum of salt."

"The chemicals in A will make a reaction and the salt will be stronger."

Incorrect Choice, Correct Concept:

"You cant't taste the difference between mildly salty water and slightly salty water."

"B has a higher ratio of water to salt."

Incorrect Choice, Incorrect Concept:

"They are equal portions."

"Because the addition of distilled water should not add a saltier taste."

"Distilled water is purer and will hold the taste more, so B will taste more salty than A."

SOLUTION No. 2

A solution of copper sulfate in water is divided into two exactly equal portions, A and B. A is left alone. B has distilled water added. Which statement is true? (check one)

A contains more copper sulfate than B ☐

A contains less copper sulfate than B ☐

A and B contain the same amount of copper sulfate ☐

Give the reason for your choice. ____________________

________________________________________________

________________________________________________

________________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| more | 0 | 8 |
| less | 0 | 6 |
| same | 75 | 9 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"There is the same amount of copper sulfate in each because none has been removed from either A or B."

"No copper sulfate was added or removed from either of the portions. There will still be the same amount."

"The amount of copper sulfate doesn't change just because water was added."

Correct Choice, Incorrect Concept:

"Because they have the same density."

"Copper is not soluble in water."

Incorrect Choice, Correct Concept: NIL

Incorrect Choice, Incorrect Concept:

"B has had distilled water added therefore would lessen amount of copper sulfate."

"The density may change but the mass remains constant."

"Because distilled water has no impurities."

"It has less copper sulfate because it has been diluted."

EQUILIBRIUM No. 1

Solid sugar is added to water until a solution is formed with excess solid sugar remaining in the flask. Under the given conditions the dissolved sugar molecules are in equilibrium with the undissolved (solid) molecules

sugar(aq) sugar(s)

Now suppose additional solid sugar was added and left for several hours. How would the amount of dissolved sugar, i.e. sugar(aq), change?
(check one)

There would be more dissolved sugar ☐

@ There would be less dissolved sugar ☐

The dissolved sugar would not change ☐

Give the reason for your choice. ______________________

____________________________________________________

____________________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| more | 0 | 9 |
| less | 7 | 11 |
| no change | 37 | 6 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"The addition of sugar does not change the ability of water to dissolve sugar."

"The solution is already saturated."

"Because it can't hold any more."

"The equilibrium can't be affected by adding solid sugar."

Correct Choice, Incorrect Concept:

"The dissolved sugar would be equal to the added solid sugar."

"Law of Definite Proportions - a certain amount of one substance can mix with the same amount of another substance."

Incorrect Choice, Correct Concept:

"Would not be able to dissolve this sugar, so it would build up."

"When temperature decreases, sugar would crystallize out."

"Evaporation would leave more undissolved sugar."

Incorrect Choice, Incorrect Concept:

"Because more sugar will dissolve."

"The solid sugar has had time to dissolve."

"Some sugar is precipitated."

EQUILIBRIUM No. 2

The water in a swimming pool is continuously being pumped out, filtered and returned to the pool. If the pump can be made to work faster will the water level in the pool:
(check one)

rise? ☐

fall? ☐

not change? ☐

Give the reason for your choice. ______________________

________________________________________________________

________________________________________________________

________________________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| rise | 0 | 5 |
| fall | 5 | 8 |
| not change | 144 | 14 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"Because you are not adding water, just speeding it up."

"The same amount of water is being pumped out and in. It doesn't matter how fast."

"As quick as the water is leaving the pool, it is also entering the pool."

"Because there is no new source of water, it is just the same water returning."

Correct Choice, Incorrect Concept:

"The Law of of Conservation of Energy."

Some students left the reason blank

Incorrect Choice, Correct Concept:

"When you pump and filter, you lose a small amount of water."

"Because some of the water will disappear by evaporation."

Incorrect Choice, Incorrect Concept:

"Fall because it can suck the water out faster."

"Because the water is not kept in the filtration system so long the extra water will make the level rise."

EQUILIBRIUM No. 3

Picture a sand box on a beach. Two children are playing with identical shovels. Every time one child throws a shovel-full of sand out of the box the other one throws a shovel-full of sand into the box. Now suppose both children start shovelling twice as fast. What will happen to the amount of sand in the box?
(check one)

It will increase ☐

@ It will decrease ☐

It will stay the same ☐

Give the reason for your choice. ______________________

______________________________________________

______________________________________________

______________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| increase | 1 | 4 |
| decrease | 4 | 1 |
| stay the same | 112 | 7 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"When one shovel-full of sand is sent out of the box there will be shovel-full in, so no matter how fast their speed is, the amount of sand will still remain the same."

"The same amount of sand going in is coming out."

"It will be the same, but the amount moving will be twice as fast."

"The same reason for dynamic equilibrium where one cancels the other."

Correct Choice, Incorrect Concept:

REASON LEFT BLANK

Incorrect Choice, Correct Concept:

"Decrease, because the child shovelling just has to fling it, the other must aim at the sandbox and will likely miss sometimes."

"Slowly lose sand because you can't measure anything exactly."

Incorrect Choice, Incorrect Concept:

REASON LEFT BLANK

EQUILIBRIUM No. 4

Morakite is a mineral which comes from the mine in chunks about the size of footballs. The chunks, when soaked for weeks in sulfuric acid yield an unusual substance "morakalium" and a waste sludge of unreacted morakite, acid and by-products. The quantities reacting are:

| Morakite | + Sulfuric acid | → Morakalium | + Wastes |
|---|---|---|---|
| 100 kg | 20 kg | 12 kg | 108 kg |

If the morakite ore was ground to a fine powder before being mixed with the acid, the reaction would be finished in days instead of weeks, but would the yield of morakalium be greater, smaller or the same as 12 kg from each 100 kg of ore?
(check one)

greater yield ☐

smaller yield ☐

same yield ☐

Give the reason for your answer. ______________________

______________________________________________________

______________________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| greater | 1 | 13 |
| smaller | 1 | 17 |
| same | 75 | 20 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"Grinding the ore does not increase amount, it just exposes more surface."

"It decreased the reaction time, but not the chemical properties."

"Each small particle reacts the same way as a large particle would, only faster."

Correct Choice, Incorrect Concept:

"Law of Definite Composition."

Incorrect Choice, Correct Concept:

"The powder would get mixed up in the wastes (some of it) and would be lost."

Incorrect Choice, Incorrect Concept:

"The inside of the chunk is exposed to acid which would offer further waste."

"Because all the morakite would be crushed and this would make the yield smaller."

"Since the process if faster, more morakalium would be formed."

EQUILIBRIUM No. 5

When substance A is mixed with substance B a fast reaction occurs to produce AB. But AB decomposes quickly to release A and B, thus:

$$A + B \longrightarrow AB$$

If 1000 g of A is mixed with 1000 g of B, within three minutes there will be a situation in which 500 g of A and 500 g of B can be found un-reacted and 1000 g of AB are formed. This appears to be a stable situation.

@ Now suppose a method is found to slow down the reactions forming and decomposing AB so that both take three days instead of three minutes. After a week will there be more or less than 1000 g of AB, or will the amount be the same?

(check one)

more ☐ less ☐ same ☐

Give the reason for your choice. ______________________

______________________________________________

______________________________________________

| ALTERNATIVE | NUMBER OF STUDENTS RESPONDING | |
|---|---|---|
| | CONCEPT CORRECT | CONCEPT INCORRECT |
| more | 0 | 3 |
| less | 1 | 10 |
| same | 60 | 21 |

TYPICAL REASONS

Correct Choice, Correct Concept:

"The time taken will not increase nor decrease the amount of AB or A or B."

"The reaction in unchanged. It just takes a longer period of time."

"Because once a reaction has gone as far as it can it won't go any further whether it is speeded up or slowed down."

Correct Choice, Incorrect Concept:

"It has reached its saturation point."

"It is debatable. It depends on how much solvent (if any) is left to dissolve the solute."

"It just will [be the same]."

Incorrect Choice, Correct Concept:

"It has had a chance to evaporate in all of this time. This is showing the use of a negative catalyst. It slows down the reaction."

Incorrect Choice, Incorrect Concept:

"It expands more when allowed to slow down."

"Because of a more severe change it would produce more."

"AB decomposes to form A and B so that tht 1000 g will slowly decay back the other way."

# CHAPTER 9

## STORYLINE INSTRUMENTS

The instruments in this set were NOT designed for testing purposes. They are interesting, unique and challenging problems. They are the types of problems that may arouse the interest of the highly motivated student of science as well as the not so highly motivated student. The problems were designed as "pep-up" during a study of any topic related to calculations. Use them as a change of pace.

Hopefully, you and your students will enjoy the fun of "sciencing" as they read and solve the problems.

1 135 g of zinc reacts with excess hydrochloric acid. The hydrogen produced is collected at 20.0°C and 85 kPa. How many moles of hydrogen will be collected? What volume will the hydrogen occupy? If these reactions occurred on the surface of the moon, how many moles of the $H_2$ would be produced? What volume would the $H_2$ occupy? What additional information do you need to answer this question?

2 Space people have just landed on an island in the Pacific. They see a strange sight, a smoke-like gas coming out of a cone-like part of the island. They collect 600 mL of this gas at 227°C, for experimental purposes. What volume will the gas have once they get back to the coast where the temperature is 30°C? Assume that the pressure of the atmosphere is constant.

3 It is a hot day and you are returning to Toronto from Montreal. Before taking off you check the pressure of your tires. Later, you find yourself almost to Quebec City (oops-took the wrong turn). So you stop for a map and check your tire pressure again, before continuing on the right track. Explain what has happened and support your answer using the gas laws!

4 Explain why tire blow-outs on ten-speed bicycles occur on the hottest day of summer. How could the situation be remedied?

5 The effects of pressure on deep sea divers is well known. For each 10 m that the diver descends the pressure increases by 101 kPa. The body will transmit pressure freely through all its fluid portions directly to but not necessarily into the air spaces which are present (sinuses, lungs, spaces associated with the ears etc.). If the space has a soft, movable wall, will the increased pressure cause the space to expand or contract? Why? What gas law does this describe?

6 Pressure also affects the ascent of a diver. If a woman is at a depth of 30 m and ascends, what will happen to the volume of the air in her lungs? (She is going from 404 kPa to 101 kPa of pressure). What law does this follow?

7 Explain why opening a bottle of carbonated pop causes the liquid to bubble (release gas).

8 Vegetables may be cooked in a pressure cooker in very much shorter time than in an ordinary saucepan. Account for this.

9 Seven litres of a gas collected from the surface of the planet Mars has a mass of 20 g at 180°C and 66 kPa. What is the density of the gas on earth at S.T.P.?

10 You are on a camping trip and wish to heat a can of Ivan's Irish Stew for supper. So as not to dirty a saucepan you decide to heat the stew in the can. You are having trouble deciding whether to take the lid off before heating the stew. What decision would you finally make and why?

11 You are a member of a manned flight to planet X. On landing you find that the atmosphere is 25% $H_2O$ vapour, 50% $CO_2$, 4% $O_2$ and 21% $N_2$. The normal atmospheric pressure on planet X is 800 kPa. What contribution does each gas make to the air pressure on planet X?

12 You want to send chlorine gas, $Cl_2$, safely from Vancouver to Kingston. Chlorine gas is very poisonous. You have a 5 L cylinder that will withstand a pressure of one hundred atmospheres. The cylinder will be kept at 0°C throughout the trip. How many moles of chlorine can you safely ship?

13 Your task is to boil 1 L of water on a hot plate with "infinite heat", in an open container, for half an hour. You are to do this once at sea level, and once at the highest point of Mount Everest.

Your problem is this: find the situation which results in the evaporation of the greatest amount of water.

Should you be unable to complete the task for any reason, make a prediction instead and explain you prediction.

14 Coke is used in the steel manufacturing process. Coke oven gas is a by-product of the process. A certain steel plant (Acme Steel) produces 150,000 L (at 101 kPa of pressure) of coke oven gas per 24 h period. Government legislation allows only 5% of that amount to be burned off into the atmosphere due to the gas's pollution effects. The remaining gas has to be stored in a tank. Once every ten days the tank is emptied to provide for the plant's internal fuel needs. The tank was designed to withstand a maximum pressure of 1 MPa. The temperature range for the locality where the plant is located is $-20^{\circ}C$ to $+30^{\circ}C$. The temperature of the gas at any one time can be assumed to be the same as the outside temperature. What is the smallest acceptable volume of the tank?

15 The design for a modern rocket ship called for it to be able to make a return trip from the earth to the moon and back. The fuel to be used was a gaseous fuel. The oxygen:fuel volume ratio called for in the design specifications was 15:1. The total trip would require 10,000 L (at $0^{\circ}C$ and 101 kPa) of fuel. The pressure in the oxygen storage tank was required to be maintained at 25 times atmospheric pressure at an initial temperature of $-30^{\circ}C$? What would be the minimum and most efficient size of the oxygen tank? Suggest two ways in which the pressure could be kept constant.

16 Captain James T. Quirck of the spaceship Avogadro must be transported to a distant planet inhabited by Clangons, the fiercest of all interplanetary warriors. So that he will be well-armed, Quirck must modify the workings of his GASER (gas amplification by simulated emission of radon (Rn)). In Federation territory the sample of gas in Quirk's GASER has a volume of 452 mL when measured at $87^{\circ}C$ and 7.5 kPa pressure. In Clangon territory the pressure at the star's surface has been found to be 101 kPa and the temperature $0^{\circ}C$. What will be the volume of the gas in Quirk's GASER if he must do battle on the planet inhabited by the Clangons?

17 At the ACME Chemical Company, ammonia ($NH_3$) is stored in a tank which is connected via a stopcock to a second "safety tank". When the pressure is too high in the first tank, the stopcock may be opened, allowing gas to escape into the second tank. Thus an explosion into the atmosphere is prevented. Last summer the $NH_3$ in tank 1 was at 18.2 MPa. Since this exceeds the "safety level" pressure of 15.2 MPa, some $NH_3$ was allowed to escape into the previously evacuated second tank whose volume was 500 L.

When equilibrium between the tanks was reached it was noted that the temperature had not changed and the new pressure was 14.2 MPa. What is the volume of the first tank?

18 As the space shuttle approaches its landing dock, the commander notices a rise in the temperature of the gas used to propel the craft. As he calls for a "red alert", aboard his ship, he is aware that should the pressure reach 500 MPa, then all will be lost. The gas present is in a tank having a volume of 68 L and normally is maintained at a pressure of 250 MPa and 25°C. What temperature will cause the destruction of the ship?

19 It was a nice day on Wizard Land with a temperature of 300°C and the barometric pressure steady at 10 kPa. It was also an important day for today their biggest spaceship (2 earth stories high) was to be teletransported to earth. Teletransporting involves a procedure whereby an object could be made to disappear in one place and <u>instantly</u> appear in another predetermined spot. It was now time for the president of Wizard Land to press the button which would send this exploratory vehicle instantly to earth. The scientists were around their instruments awaiting the moment as the vehicle would immediatly begin to send information back when it arrived on earth. The countdown ...4...3...2...1 button pressed... but wait... what is wrong?? Something has happened. The space ship has collapsed to the thickness of a pancake!! Little did they realize that it was also a nice day on earth. What happened to the ship?

20 In the roasting of nickel ore, sulfur dioxide, $SO_2(g)$, is produced as a byproduct. Given that the roasting process consists of reacting nickel sulfide, NiS, and oxygen to form sulfur dioxide and nickel oxide NiO, write a balanced equation for the process.

The ore also contains other sources of sulfur, approximately 70% of which is removed in some way before it gets into the atmosphere as $SO_2$. The largest nickel smelter in Ontario produced 2700 mg of sulfur dioxide per day in the early 1980's.

Given the proper atmospheric conditions, $SO_2$ can be oxidized into sulfuric acid, which then mixes with atmospheric water vapour and falls as acid rain.

$$SO_2(g) + \frac{1}{2} O_2(g) + H_2O(g) \rightarrow H_2SO_4(g)$$

In order to protect the environment it is proposed to make the sulfur dioxide into sulfuric acid at the factory, instead of releasing it into the atmosphere. How many megagrams of $H_2SO_4$ could be produced from one day's production of $SO_2(g)$? How many Winchester bottles of concentrated sulfuric acid is that? (concentration = 18 mol/L, specific gravity = 1.84, mass = 4 kg)

21 You are a chemical engineer, working for an industrial firm producing hydrogen gas for the space programs. Your firm decides that the reaction between zinc metal (Zn) and hydrochloric acid (HCl, 30% by mass) producing zinc chloride and the desired product, $H_2$ gas, is the most economical means of producing the gas considering the plant's geographical location in relation to readily obtainable raw materials needed in the process. The industrial process is such that $H_2$ gas is collected in ampules. Your task is to calculate the minimum mass of reactants needed to produce 6 g of $H_2$ in each ampule.

22 If a plant respires through the pores in its leaf structures by taking in $0.1 \times 10^4$ mol of $CO_2$ per hour at $20^\circ C$ and 90 kPa, what volume of $CO_2$ will be taken in by the plant per hour on a hot summer day at at $29^\circ C$ and 104 kPa.

23 An astronaut carries a cylinder of air to breath while on a "space walk" to repair an outside panel of the space station in which he lives. The cylinder was charged with 120 L of air before he left earth. The pressure at filling time was 101 kPa measured in the earth control station at 20°C. During the "space walk" the external temperature is 150 K and the pressure of any air present is 1.5 kPa. Assuming that the astronaut breathes 2 L of air every 5 s while out of the space station, how long will the air last? How long could the cylinder be used "just underwater" on earth?

24 HAPPINESS IS A BIG RED BALLOON!

It was Snoopy's birthday and Charlie Brown gave him a big red balloon full of helium. Then Peppermint Patty invited Snoopy over for a party, and so the balloon wouldn't feel lonely he took it along with him.

But outside it was winter, and the poor balloon and the helium inside it cooled to -40°C and began to shrink. When it had been filled in a nice warm factory at 25°C it had a volume of 1 L! What was its new volume?

Then he went and joined Peppermint Patty's other friends and he was soon having such a good time that he forgot all about the balloon.

Meanwhile, the fire was so hot that the temperature of the balloon and the gas inside it rose by 10°C per minute. Gradually the gas expanded till the balloon was twice the volume it had been when it was filled in the factory.

b What was the temperature inside the balloon when this happened?

c How long did it take to reach this temperature?

At this point the balloon began to change. The balloon would have burst when the pressure inside it was 1 1/5 times greater than atmospheric presure but luckily Snoopy remembered the balloon just in time to run into the kitchen and snatch it away from the fire - one second before it would have burst!

d What was the pressure inside the balloon at this point?

e How long had Snoopy left the balloon in front of the fire?

25 You are a member of a team of scientists who will be spending several months at the North Pole doing meteorological studies As part of your investigation, you will be sending up a total of 200 helium filled balloons. Each balloon must be filled to a volume of 10 L in order to carry up the instruments attached to it. You will be filling the balloons from cylinders whose volumes are 10 L. The cylinders were filled to 2020 kPa at $20^{\circ}C$. Because of the difficulty of transporting your equipment, you want to take along as few cylinders as possible. What is the minimum number of cylinders you will need to complete your investigations? (You can expect to be working at temperatures as low as $-40^{\circ}C$ and a constant pressure of 101 kPa).

26 You've just fixed a flat on your bicycle, and want to fill it with air to a pressure of 600 kPa. You don't have a gauge to measure the pressure, but you know that the tire's volume is 1 L when it is expanded. You have a hand pump that puts (at STP) 0.250 L of air into the tire each time you pump it. How many times must the pump be pumped to fill the tire to 600 kPa pressure?

27 Stomach acidity can be neutralized, by taking a sodium bicarbonate solution ($NaHCO_3$). The reaction is as follows:

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2(g)$$

The $CO_2$ (gas) is given off as a "burp". How big a burp (that is, how many litres of gas) will one have if 0.1 mol of HCl is neutralized by the $NaHCO_3$ in the stomach? Body temperature is $37.2^{\circ}C$, and pressure in the stomach is atmospheric pressure, 101 kPa.

28 Your school has just orbited its first space shuttle serviced long term, living-lab station. You are on board as environmental systems analyst. One day maintenance personnel report to you that the simple device you've constructed to measure atmospheric pressure indicates that, with respect to a standard earth pressure of 101 kPa, the system atmosphere pressure is low and dropping. Is the situation dangerous? What alternative hypotheses are possible as explanations for the problem?

How would you eliminate some of these hypotheses? Describe the simple pressure measuring device you designed.

29 Your friend has "gambler's disease". He bets you that his 2 mL of HCl will diffuse through a 100 cm length of glass tubing faster than your 2 mL of $NH_3$ will pass through a 130 cm length of identical tubing. He gave you 5:1 odds that he will win. He will increase the odds to 10:1 if you come up with a foolproof means of judging the race.

(1) What "foolproof means" would you use to judge the race race (and increase the odds)?

(2) Who will win? Why?

(3) If you win, how much do you bet? You need $100.00 for next weekend.

30 A balloon contains 1000 L of air maintained at a temperature of 150°C and a pressure of 88.0 kPa. A member of the crew accidently inflicted a puncture of 2 cm diameter in the balloon. The resultant loss of air was 150 L before the puncture was repaired. In order to avoid a work stoppage what temperature would the air in the balloon have to be adjusted to, so as to maintain a pressure of 88.0 kPa?

31 A mountaineer has gone climbing up a mountain until he reaches the peak at a height of 3000 m. At this point he decided that he would like a pot of tea. Using a propane burner he boils his water and makes tea, only to find out that the water was not really hot. Explain how the water could boil without being really hot.

32 Fish are found at the very bottom of the oceans yet when samples of these fish are brought to the surface they are almost always dead. Suggest why the trip to the surface might kill them.

33 Jane has just received a recipe from a friend for making bread. The friend was recalling the recipe from memory so all may not go as planned! The recipe calls for 22.5 mL of yeast and yields a piece of dough of 500 mL volume. A perfectly formed loaf has volume of 3 L. Each 15 mL of yeast produces 1.8 L of $CO_2$ at STP. Will Jane produce a perfectly formed loaf of bread or be scraping the dough off the oven if the bread is baked at 190°C and the dough exerts 150 kPa pressure on the $CO_2$ bubbles?

34 A toxic gas is produced as a waste product by an oil refinery at Eckston. The government has recently prohibited the company from releasing the gas untreated into the air. Detoxifying equipment is extremely expensive. A company in Wyston comes to the rescue announcing that they can use the gas in manufacturing another product. The gas is to be transported in trucks at 15.0 MPa pressure. The tank walls can withstand 16.5 MPa pressure. The first truck loads up in Eckston at $-8^{o}C$ and drives towards Wyston at a balmy $20^{o}C$. Is the truck likely to reach its destination without blowing up?

35 The year is 2050. Coca Cola is intending to develop and shoot a TV commercial on another planet. The temperature conditions on the planet vary from 400 K to 450 K. The carbon dioxide in the bottled Coke will blow the cap off if it's partial pressure reaches 1.5 times normal earth atmospheric pressure (assume the planets's atmospheric pressure is that of earth's). Will the advertisers be able to take a regular bottle of Coke to the planet or must they affix a tighter fitting cap?

36 A blimp is stationed over the 1976 Olympiad in Montreal for advertising. In order for the company's message to be straight, the material or outer skin must be taut. A volume of at least 16,000 $m^3$ is necessary to keep the material taut. The weather conditions at an altitude of 600 m on the first day are 99kPa pressure and $22^{o}C$. The blimp has 406 kPa pressure exerted by the enclosed helium creating a volume of 16,500 $m^3$. A low pressure system moves into the area the next day. The pressure drops to 95 kPa and the temperature to $10^{o}C$. Will the lettering appear wrinkled? If so, to what temperature must the helium be heated to "unwrinkle" the letters?

37 Agent 86 opens a vial of knockout gas at the end of a hallway 5 m from a guard. But Agent 99 is 4 m away and is wearing a powerful perfume, which, if the guard notices means capture. The knockout gas has a molar mass of 225 g/mol and takes 1.5 s to work. The perfume odour has a molar mass of 400 g/mol and will reach the guard in 12 s. Will Agents 86 and 99 succeed?

38 One of the problems in home wind generators, as an alternative energy source, is storing energy for windless days. If excess energy from the generator is used to electrolyze water, the hydrogen produced can be burned later. However, storing hydrogen can be a bit of a problem. To illustrate, how many cubic metres would 10 g of $H_2$ occupy at STP? Suggest ways of getting around the storage problem and rate the difficulty involved in each suggestion.

39 You are to go for a flight in a hot air balloon. The volume of the balloon is 60000 $m^3$. Your propane heater can raise the air temperature in the balloon 20$^oC$ above that of the atmosphere (26$^oC$, 80% nitrogen, 20% oxygen). The atmospheric pressure is 104 kPa. If the mass of the balloon and basket is 80 kg with you in the basket, will the balloon fly and if so how much extra mass might if lift?

40 A diesel engine has 6 cylinders and the displacement (volume of cylinders) is 2.4 L. The volumes in each cylinder head at compression is 20 mL. What temperature would the compressed air be, at compression, if the compression ratio is 20:1 ? The compression ratio is the ratio of pressure before and after compression.

The inital temperature in the cylinder is 80$^oC$. If the fuel injection is done at maximum pressure and the fuel needs to be above 400$^oC$ to ignite, will the engine run?

41 A balloon, diameter 10 cm, is taken to the bottom of a swimming pool where the pressure is 3 times atmospheric. If the air is at 22$^oC$ and the pool at 15$^oC$ calculate:

1. the diameter of the balloon at the bottom of the pool, before the air temperature in the balloon has started to drop.
2. the diameter of the balloon, once it equilibrated in temperature with the pool water

(Ignore the effect of elasticity of rubber; assume that the balloon simply encloses the appropriate volume of gas).

42 A scientist, working in a room 4.0 m long, 3.0 m wide and 2.6 m high, inadvertently spilled 35.0 mL of 1.00 mol/L HCl into a beaker containing excess silver cyanide, AgCN. (Assume that hydrogen cyanide gas is insoluble in water at 27$^\circ$C):

a) Write a balanced equation for the reaction.
b) How many litres of HCN were produced?
c) What was the concentration (in mol/m$^3$) of HCN produced in the room?

d) What did the scientist do?

43 What happens when you mix stomach acid, HCl(aq), with baking soda, $NaHCO_3$?
a) Write a balanced equation
b) A glutton consumed 5.5 g baking soda to neutralize an excessively acid stomach. If his body temperature were 37$^\circ$C, how many litres of gas would be generated within his body? Do you recommend this practice?

44 Terry's mother asks him to dry the dishes. Terry procrastinates but eventually he starts drying the dishes. His mother has already washed the glasses and they are dripping in to a tray containing water to a depth of 0.25 cm. Terry notices that the inverted gasses have "sucked up" some of the water. They are one-sixth full of water. How hot were the glasses when they came out of the dishwater? The temperature of the room is 22$^\circ$C.

45 Arnold the astronaut collects a gas sample from the surface of the planet of Mars. He knows the atmospheric pressure of Mars is 68 kPa. He analyses the sample and finds that it consists of $4.0 \times 10^{12}$ molecules of oxygen, $2.0 \times 10^{12}$ molecules of carbon dioxide and $4.0 \times 10^{12}$ molecules of a gas unknown on earth. What is the partial pressure contributed by this unknown gas?

46 A weather balloon containing 40 L of helium is anchored at an airport about to take off. The airport reports the air pressure as being 100 kPa and the temperature as 28$^\circ$C. The engineer says that the balloon's volume must not exceed 150 L or the balloon will break. The engineer wants the balloon to rise to an altitude of 650 m. At this altitude the air pressure is 47 kPa and the temperature is 8$^\circ$C. Will the balloon break?

47 Sulfur dioxide is being emitted from a smoke stack at a paper mill. How long will it be before the people in a house 1000 m away smell the gas? (Hint: from experimentation we know that $HCl(g)$ travels 50 cm in 10 min)

48 Two Martians, visiting earth, had a gadget to measure temperature by recording changes in pressure. The gadget was a solid walled container filled with Argon. The container was first made at a temperature of $4^{\circ}C$ and a pressure of 76 kPa. The Martians recordered a new pressure of 78 kPa when taking the "temperature". What was earth's temperature that day?

49 A Chemist recently discovered a new compound and named it ecksite. In the gaseous state at $25^{\circ}C$ and 202 kPa pressure, 6.11 L of ecksite has a mass of 403 g. What is the relative molecular mass of ecksite?

50 The "Chill" temperature scale was used to measure temperatures of a gas in the following experiment. The following values were obtained for volume vs temperature measurements of a gas at constant pressure.

| VOLUME | TEMPERATURE |
|---|---|
| 10 mL | 5 "chill" |
| 20 mL | 25 "chill" |
| 30 mL | 45 "chill" |
| 40 mL | 65 "chill" |

What is absolute zero in terms of degrees "chill"?

51 A student developed a new device which collects exhaust fumes from a car. The exhaust fumes are pumped into a constant volume collection vessel. The wall of the vessel has limited strength, and once the pressure exerted from the inside of the vessel exceeds 1000 kPa it will break. The vessel initially contains air under the normal air pressure of 100 kPa After one hour, the pressure on the inside of the flask is 400 kPa. How much longer can the car run at the same rate of exhaust emmision before the vessel breaks? The temperature is maintained at a constant value.

52 John was watching TV in the living room at the same time as Mark was working in the kitchen. He took a rotten egg out of the refrigerator and put it on the stove. At the same time, he absent-mindedly opened the gas valve of the stove. Which should John discover first: the gas leak or the rotten egg? Find the ratio of the velocities of the two gases. One came from the stove, $CH_4(g)$, and the other, from the rotten egg, $H_2S(g)$.

53 When Johnny took his little brother to the circus, he bought him a large yellow balloon filled with helium. Naturally Johnny's brother let go of the string about 5 min after he got the balloon. With tears in his eyes he turned to Johnny and asked, "What will happen to my balloon when it gets up to the sky?" What would happen to the balloon? Why?

54 My friend Zeke has a great car - a beaten up old one. It's a small car with a volume of about 2 $m^3$ inside the cab. Normally if you force 10 people in the car, there is only a little volume left for the air. When no people are inside the car Zeke must use arm pressure equivalent to 85 kPa to close the door from the outside. How much volume is left inside the car with 10 people inside if Zeke must exert 104 kPa pressure to close the door then? (Assume no air escapes when all 10 people get inside the car.)

55 Your are on the plane to Arrabis. On this planet which has strange atmospheric conditions, all gases behave as the "ideal gas" on earth. There is a special gas called Kirleon (Kl) which Dr. Symbrosis is studying. He is taking the volume of a fixed mass of gas at a fixed pressure, while varying the temperature. His experiment gave the following results:

| VOLUME (mL) | TEMPERATURE (the local temperature scale) (in $^oX$) |
|---|---|
| 478 | 70 |
| 437 | 40 |
| 425 | 28 |
| 400 | 10 |
| 387 | 0 |

a) What value did Dr. Symbrosis find for absolute zero on Arrabis? (in $^{o}X$ and K) Why is it not $-273^{o}X$?

b) What would be the volume of 500 mL of Kirleon at $30^{o}X$ if the gas was heated to $98^{o}X$?

56 Consider the Rutherford model of the atom. Explain Superman's invulnerability in respect to this model.

57 Hydrogen sulphide is as toxic as hydrogen cyanide gas. At $27^{o}C$ $H_2S$ is fatal to humans when its partial pressure is 20 kPa. Calculate the mass of $H_2S$ which gives a fatal dosage in a room 210 $m^3$ at $27^{o}C$. In practice, far fewer people die of $H_2S$ poisoning than of HCN poisoning. Why?

58 While diving with SCUBA gear off Australia's Great Barrier Reef, Jacques Yves Cousteau and two crew members of the Calypso (his boat) enter a submarine cave at a depth of 30 m. Their job finished, Jacques and his two dive-buddies start back to the mouth of the cave only to find it being patrolled by five very large Great White Sharks (the kind that aren't fussy about what or whom they eat!)

Knowing as he does that sharks usually linger no longer than 10 min in any one place, Jacques looks at his Scuba pressure gauge to see if he has enough air to wait it out. The pressure gauge reads 1500 kPa - this is the pressure of air in his tank.

If Jacques inhales 500 mL with each breath, and his breathing rate is 10 breaths per minute, and the volume of his scuba tank is 10 L, will Jacques have any air left after a 10 min wait? If so, what will be the final pressure (after 10 min) in the tank. (Remember that a depth of 10 m of sea water corresponds to a pressure of about 202 kPa and that the air in a person's lungs must be equal in pressure to the fluid surrounding his rib-cage!).

59 Arriving on the scene of a suspected homicide in the east end of London, famed detective Sherlock Hemlock found the body. The victim was found lying face down with a broken neck and a definite odour of alcohol prevailed. The scene at first looked to be an accident but Sherlock Hemlock's experienced eye suspected foul play. Knowing as he does that a person can kill himself only after the blood alcohol exceeds 0.02%, Hemlock took a sample of the victim's blood and found that he collected 0.5 L of blood. He then separated the alcohol in the blood and found 5 mL of alcohol.

Does the volume of alcohol meet the necessary level of drunkenness to account for death by accidental intoxication?

60 Peter Piper purchased a peck of pickled peppers. One bushel consists of four pecks of pickled peppers. The average bushel contains 300 pickled peppers. The average pickled pepper contains 100 mL of 0.2 mol/L acetic acid. How many moles of acetic acid did Peter Piper purchase?

61 After the first three weeks of school Miss Petriola Schoolteacher is complaining of severe pains in the abdominal region. She decides to see a doctor. The doctor informs Miss Petriola Schoolteacher that she is suffering from a duodenal ulcer.

Suppose Miss Schoolteacher has an $8 \times 10^{-2}$ mol/L concentration of HCl in her gastric juice. If her stomach secretes 3 L of gastric juice per day how many antacid tablets must she take to neutralize the acid in her stomach?

Assume that each tablet contains 2.6 g of $Al(OH)_3$.

62 It is often thought that the first visitor to Ontario from Quebec came as a result of a breakaway during a hockey game on the St. Lawrence River. Evidence to support this theory has recently been put forth with the discovery of a very old yet well preserved Victoriaville hockey stick during excavation work in Toronto. Analysis of the wood indicates that it has radioacitivity due to carbon-14 of twelve disintegrations per minute per gram of carbon. From this data, calculate how long ago the historical event took place.

($t_{1/2}$ carbon-14 = 5750 a)

63 In 1978 a science student doing a growing room project injected a tree with carbon-14 until the disintegration rate was one and a half times the normal 15 disintegrations per minute. A few days thereafter, one of the art students cut down the tree to fashion a custom-made baseball bat. Hundreds of years later, scientists discovered the skeleton of the student still clutching the bat. A carbon-14 dating of the bat indicated that the student had just been killed, and a murder investigation was instigated immediately. In what year was the skeleton discovered?

($t_{1/2}$ $^{14}C$ = 5750 a)

64 The most immediate danger when the fuel tanks of a military aircraft are punctured by enemy fire is not loss of fuel, but explosion. This is especially true when the tanks are only partially full, because they contain not only fuel but a mixture of fuel vapour and air.
This danger was greatly reduced when an aircraft designer thought of closing the system so that air could not enter, and replacing the fuel (as it was used) with nitrogen. The nitrogen would be carried on board the aircraft in a compressed gas bottle, and fed to the fuel system by a regulator.
The designer has assigned you the problem of the detail work on this idea.

i) The Super Blackfly MkX has a fuel capacity of 387 L. Due to the small size of the aircraft the designer can only allow enough space for compressed gas bottle whose volume is 3.5 L.

a) What pressure of nitrogen will be needed if enough room is to be provided to fill the fuel tanks once at atmospheric pressure?

b) The aircraft will be equipped with self-sealing fuel tanks that can repair small punctures in themselves. While the tanks are performing their self-sealing operation, the pressure in them must be greater than atmospheric (say 1300kPa), so that no air will enter the tank via the hole. The largest hole that can be repaired is sealed in three minutes. Out of such a hole nitrogen could escape at the rate of 150 L/min (measured at 130 kPa). This is the worst situation you need be prepared for. With a larger hole the tanks could not self seal, so you could not hope to provide enough nitrogen to keep them full of nitrogen all the way back to base. What pressure would you need to carry in the compressed gas bottle to be prepared for two such punctures? Do you think such a pressure would be feasible?

ii) The Junebug Deluxe bomber has a fuel capacity of 9800 L. More room is available, so the designer has not limited the volume of the gas bottle. However, for technical reasons concerned with filling the bottle in the field, he does not want a pressure greater than 1300 kPa. What size container is needed to provide a pressure in the fuel tanks of 100 kPa (no provision for punctures)?

iii) Although the volume represented by the pressure vessel is not prohibitive, the mass of metal needed to make it could be a detriment. Outline an alternate solution to the problem of excluding oxygen from the fuel tanks?

65 The little red-haired girl's birthday was approaching and Charlie Brown had decided to buy her a present. He read an article in the newspaper about the discovery of a new species of fish by a renowned biologist from the University of Greater North Central Ontario. He claimed the new species was a very beautiful and friendly one, so Charlie thought it would make the perfect gift. A colleague of the biologist, a renowned chemist found that the natural habitat of the fish was an aqueous acidic environment of pH 6.0. If Charlie puts 25 L of tap water, pH 7.0 into the aquarium, what volume of 0.1 mol/L $HCl(aq)$ must be added to ensure the ideal environment for the fish?

66 Your space shuttle has developed engine trouble and you are forced to land back on earth using only your glider capabilities. You know your ship will hold together, but you are worried about the oxygen tank, which is only temporary and not very well made. It holds the oxygen necessary for the survival of yourself and your crew. The gauge shows the tank contains 50.0 L $O_2$ under a pressure of 4000 kPa. It is presently at a temperature of 37°C, but you expect the temperature on re-entry to reach 295°C. The tank was only designed to withstand a pressure of 7000 kPa. Will you go ahead with the tank, or will you eject it and tell everyone to hold their breath?

# CHAPTER 10
# ESSAY INSTRUMENTS

A) S-17D (Grade 12)

1) What volume of $CO_2$ is produced at STP when 10.0 mL of ethyl alcohol is burned completely in oxygen? The density of ethyl alcohol ($C_2H_5OH$) is 0.789 g/mL.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

2) What volume of nitrogen, measured at $20^{o}C$ and 92 kPa, is required to react with calcium carbide ($CaC_2$) to produce carbon and 100.0 g of calcium cyanamide ($CaCN_2$)?

$$N_2 + CaC_2 \rightarrow CaCN_2 + C$$

3) A diboron tetrachloride sample was treated with sodium hydroxide and the following reaction occured:

$$B_2Cl_4 + 10NaOH \rightarrow 2Na_3BO_3 + 4NaCl + 4H_2O + H_2$$

13.26 mL of hydrogen formed at $25^{o}C$ and 96.25 kPa when 10.00 g of diboron tetrachloride was treated with sodium hydroxide. What percentage of the diboron tetrachloride sample reacted with the sodium hydroxide?

4) 30.0 g of $CO_2$, 42.0 g of $N_2$ and 48.0 g of $SO_2$ are mixed in a container in which they exert a total pressure of 140 kPa. Find the partial pressure of each gas.

5) 78.6 mL of nitrogen is collected over water at $22^{o}C$ and a total pressure of 90.5 kPa. What volume will the dry nitrogen occupy at STP?

6) Which contains more iron: 25 kg of siderite containing 50% $FeCO_3$, by mass, or 20 kg of magnetite containing 30% $Fe_3O_4$, by mass?

7) Why did Bohr find it necessary to propose that the energy states of the hydrogen atom were quantized?
What is meant by the "ground state" of the atom?

8) Potassium, relative atomic mass 39.1, consists of two isotopes of mass numbers 39 and 41. Calculate the percentage of isotope-39 present in potassium. What simplifying assumption has been made in your calculation?

9) You are given a sample of a white solid. Describe some simple tests you would perform to help you classify the solid as a molecular, ionic or network solid.

10) In a typical calorimetry experiment acetylene ($C_2H_2$) was burned and the heat produced was absorbed by the water in a calorimeter. Determine the <u>molar heat of combustion of acetylene</u> given the following data and assuming that <u>all</u> of heat produced is absorbed by the water (i.e. ignore any heat absorbed by the walls of the calorimeter).

volume of water in calorimeter = 250 mL
density of water = 1.00 g/mL
specific heat capacity of water = 4.12 J $g^{-1}$ $^{o}C^{-1}$
initial water temperature = 22.7$^{o}$C
final water temperature = 41.8$^{o}$C
mass of acetylene consumed = 0.400 g

11a) Calculate the percent composition, by mass, of ammonium sulphate $(NH_4)_2SO_4$.
b) Calculate the mass of aluminum metal that is contained in 1.00 kg of cryolite, $Na_3AlF_6$.

12) It is necessary to prepare the maximum possible amount of magnesium acetate by a reaction involving 15.0 g of iron(III) acetate with either 10.0 g of $MgCrO_4$ or 15.0 g of $MgSO_4$.
Which reaction will yield more $Mg(C_2H_3O_2)_2$? What mass of magnesium acetate will be produced?

<u>Skeleton equations</u>

$Fe(C_2H_3O_2)_3 + MgCrO_4 \rightarrow Mg(C_2H_3O_2)_2 + Fe_2(CrO_4)_3(s)$

$Fe(C_2H_3O_2)_3 + MgSO_4 \rightarrow Mg(C_2H_3O_2)_2 + Fe_2(SO_4)_3(s)$

13) Hydrochloric acid reacts with impure calcium carbonate to produce calcium chloride, water and carbon dioxide. A sample of impure calcium carbonate having a mass of 0.241 g was treated with an excess of HCl and 40.4 mL of carbon dioxide was produced at 27°C and 90 kPa pressure. What was the percentage, by mass, of calcium carbonate in the original sample?

14) A solution composed of silver nitrate and water and having a volume of 75 mL was treated with an excess of aqueous potassium chloride. The resulting precipitate of silver chloride was separated from the mixture, dried and found to have a mass of 0.82 g. Calculate the concentration of the original silver nitrate solution in:

(i) percent by mass
(ii) mol/L of solution

15) Iron(II) sulphide reacts with hydrochloric acid to produce an iron(II) salt and hydrogen sulphide gas; iron(II) sulphide reacts with sulphuric acid to produce another iron(II) salt and hydrogen sulphide gas. What mass of each acid is needed to react with 20.0 g samples of iron(II) sulphide ore which contain 10.0% inert material, by mass?

16) A sample of impure zinc weighing 1.30 g, and containing carbon as the only impurity, was dissolved in nitric acid and the solution was filtered. The filtrate was evaporated to dryness and the solid residue was strongly heated in air. The mass of zinc oxide formed was 1.59 g. What was the percentage of zinc in the sample?

17) A sample of a compound of mass 1.28 g was analysed and found to contain 0.627 g carbon, 0.0348 g hydrogen and 0.618 g of chlorine.
(i) Calculate its simplest (empirical) formula.
(ii) The 1.28 g sample was vapourized and found to occupy 0.195 L at S.T.P. Calculate its molar mass.
(iii) Calculate the molecular formula of this compound.

18) Complete combustion of 0.700 g of a gaseous pure hydrocarbon produced 2.20 g of carbon dioxide and 0.900 g of water. If 1.00 L of this substance has a mass of 1.14 g at 27°C and 101 kPa pressure, what is the true molecular formula of the compound?

19) A chemical compound has the following composition by mass: sodium 18.55%; sulphur 25.80%; oxygen 19.35%; water 36.30%. Determine the empirical (simplest) formula of the compound.

20) An organic compound was found to contain only carbon, hydrogen and sulphur. When 1.00 g of the compound was vaporized, it occupied 369.2 mL at 150$^{o}$C and 101 kPa pressure. When 1.000 g of the compound was completely burned in air it produced 0.5745 g of water vapour, 0.9363 g of carbon dioxide and an undetermined mass of sulphur dioxide. What is the true molecular formula of the compound?

21) A certain gas contains only carbon, hydrogen and oxygen. When 10.0 g of this gas is completely burned, 19.1 g of carbon dioxide and 11.7 g of water vapour are produced.
   (a) Calculate the percentage by mass of carbon, hydrogen and oxygen in the gas.
   (b) What is the simplest formula of the gas?
   (c) If 1.00 L of the gas at STP has a mass of 2.05 g, what is the true molecular formula of the gas?

22) A gaseous hydrocarbon is found to contain 85.72% carbon by mass. 5.360 L of the gas at -50$^{o}$C and 123.6 kPa pressure has a mass of 10.00 g. Determine the molecular formula of the compound.

23) Consider the following equation:

$$Fe + H_2O \rightarrow Fe_3O_4 + H_2 \quad \text{(unbalanced)}$$

   (a) Calculate the number of moles of hydrogen gas produced if 1 mol of iron and 1 mol of water are allowed to react until one of the reactants is completely consumed.
   (b) How many grams of iron are needed to react with water to form 3.0 mol of hydrogen gas?

24) 10 kg of soft coal containing 2.5% sulfur (by mass) was burned. Calculate how many moles of sulfuric acid could be produced assuming that the conversion of sulfur to sulfuric acid was 100% efficient.

25) A piece of aluminum was immersed overnight in a solution of silver nitrate. The following experimental data were collected:

Initial mass of aluminum = 10.28 ± 0.02 g
Final mass of aluminum = 10.10 ± 0.02 g
Mass of free silver formed overnight = 2.16 ± 0.02 g

a) Calculate
   1) the number of moles of aluminum used up in the reaction
   2) the mole ratio of aluminum to silver in the reaction

b) Write a balanced equation for the reaction.

26) A plastic bag was massed when filled with $O_2(g)$, and again when filled with gas X. Molecules of Gas X are known to consist only of sulphur and oxygen atoms. The mass of the oxygen in the bag is 0.32 g. The same volume of gas X under identical conditions has a mass of 0.80 g. Determine the molar mass of gas X.

27) A gas has a volume of 400 mL at a temperature of 25°C and a pressure of 125 kPa. To what Celsius temperature must the gas be cooled, if its volume is to be reduced to 350 mL when the pressure falls to 80 kPa?

28) What is the molar mass of a gas, 2.82 g of which occupies 3.16 L at S.T.P?

29) A 0.30 L sample of oxygen at S.T.P. is brought to 27°C and 50 kPa. Calculate the new volume of the gas.

30) Consider the following equation in answering the questions a), b) and c).

$$2CH_3OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$$

a) What volume of oxygen gas, at STP, is needed to burn 8.0 g of methanol ($CH_3OH$)?
b) Determine the mass of carbon dioxide produced from 4.0 g of methanol.
c) What volume of carbon dioxide (measured at 273°C and 75 kPa) would result from the complete combustion of 17.5 g of methanol?

31) Consult the periodic table, and write balanced chemical equations for the following reactions:

a) lithium reacting with chlorine gas
b) potassium reacting with water
c) magnesium reacting with fluorine gas
d) hydrogen gas reacting with bromine gas

32) A carbon dioxide fire extinguisher contains 4.40 kg of carbon dioxide. What volume of gas could this extinguisher deliver at 1 atm (101 kPa) and 25$^{o}$C?

33) A compound was found, by analysis, to consist of 37.5% carbon, 12.5% hydrogen and 50.0% oxygen by mass. If 200 mL of its vapour (at STP) has a mass of 0.286 g what is the molecular formula of the compound?

34) A compound consisting only of nitrogen and hydrogen contains 12.6% hydrogen by mass. When a sample of 3.00 L of the gaseous compound is heated, it decomposes to give 1.00 L of nitrogen and 4.00 L of ammonia, all volumes being measured at the same temperature and pressure. What is the molecular formula of the compound?

35) A mixture of iron filings, sugar and sand is placed on your desk. Describe how you would separate the components. Give your reasons for each step.

36) Calculate the relative atomic mass of gallium given that the relative abundance of its two isotopes is:

60.5% of ${}^{69}_{31}Ga$ and 39.5% of ${}^{71}_{31}Ga$

Explain each step in the calculation.

37) In magnesium oxide, the magnesium ion is surrounded by 6 oxygen ions. Explain why the formula for magnesium oxide is $MgO$ and NOT $MgO_6$.

38) Sulphur dioxide is emitted by a pulp and paper mill. Laboratory experiments have shown that HCl gas travels 5.0 cm/min. How long would it take for $SO_2$ gases to reach a house 1.0 km away, assuming that air remains totally calm? Does this value seem reasonable to you? Why?

B) S-17E (Grade 13)

100) At 500 K the system $A_2(g) + B_2(g) = 2\,AB(g)$
is in equilibrium. The concentrations of the species in the reaction vessel are

| | |
|---|---|
| $A_{2(g)}$ | 0.04 mol/L |
| $B_{2(g)}$ | 0.20 mol/L |
| $AB_{2(g)}$ | 1.00 mol/L |

a) Calculate the equilibrium constant, $K_{eq}$.

b) The concentration of $A_2(g)$ is suddenly increased to 0.16 mol/L by the addition of $A_2$. When the system comes to equilibrium again, what are the concentrations of all three species?

101) The hydrogenation of ethylene to ethane occurs as shown in the reaction:

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g) + X\text{ kJ}$$

State and explain the conditions that would produce maximum yield of $C_2H_6(g)$.

102) At a given temperature HI is 20% dissociated into hydrogen gas and iodine gas. If the equilibrium partial pressure of HI is 4 kPa, what is the partial pressure of $H_2$? What is the total pressure in the container?

103) Consider the reaction between phosphorus and hydrogen to produce phosphine

$$P_4(g) + 6H_2(g) = 4PH_3(g)$$

0.20 mol of phosphorus and 0.80 mol of hydrogen are placed in an empty 1.0 L vessel.
The vessel is sealed and allowed to equilibrate.
At equilibrium 0.20 mol of $PH_3$ are present. Determine the value of the equilibrium constant.

104) $K_{eq} = 4.0$ for the reaction: $CO + H_2O = CO_2 + H_2$.
A vessel contained 0.60 mol of CO, 0.20 mol of steam and 0.50 mol of $CO_2$ in a 1.0 L volume at equilibrium.
Calculate the equilibrium concentration of hydrogen.

105) Exactly one mole of $NH_3$ was introduced into a 1.0 L reaction vessel at a certain high temperature.
When the reaction: $2NH_3 = N_2 + 3H_2$ had reached a state of equilibrium 0.6 mol of $H_2$ was found to be present.
Calculate the value of the equilibrium constant for the reaction.

106) Consider the reaction:

$$SO_2(g) + \frac{1}{2}O_2(g) = SO_3(g) + 96.1\text{ kJ}$$

What effect would the following changes have on the equilibrium concentration of $SO_3(g)$? Explain your answer in each case.
(a) Increasing the volume of the reaction vessel at constant temperature.
(b) Increasing the temperature of the reaction vessel at constant pressure.

107) Use Le Chatelier's principle to explain why low pressure is used in the freeze-drying process (e.g. in making instant coffee).

108) The following system is in equilibrium in a reaction vessel having a volume of 5.0 L.

$$2HF(g) = H_2(g) + F_2(g)$$

The equilibrium constant, $K_{eq} = 3.1 \times 10^{-4}$.
4.0 mol of hydrogen fluoride gas and 0.20 mol of fluorine gas are in the reaction vessel at equilibrium.
Determine the number of moles of hydrogen gas in the reaction vessel at equilibrium.

109) A 50 mL volume of 0.080 mol/L calcium nitrate, $Ca(NO_3)_2$ solution is mixed with 150 mL of 0.16 mol/L ammonium carbonate, $(NH_4)_2CO_3$.
Calculate the concentrations of the most abundant ions in the solution after mixing.

110) 200 mL of 0.40 mol/L $Al_2(SO_4)_3$ solution and 200 mL of 0.20 mol/L NaOH solution are mixed.
Calculate the concentration of the aluminum ion in the solution after mixing.

111) Over 90% of people whose blood assays show an ethanol concentration of 0.003 g/mL of blood demonstrate signs of obvious intoxication.
The fatal ethanol concentration is estimated as 0.007 g/mL of blood. What volume of scotch, 40% ethanol by volume, corresponds to the difference between an intoxicating and a fatal dose for a person whose blood volume is 7.0 L. (Assume that all of the alcohol goes into the blood).
Density of ethanol = 0.8 g/mL

112) Compute the molar solubility of

$Ag_2SO_4$ ($K_{sp} = 1.6 \times 10^{-5}$) in

a) 0.00050 mol/L $Al_2(SO_4)_3$
b) 0.00050 mol/L $AgNO_3$
c) distilled water

113) Compute the molar solubility of:

$BaSO_4$ ($K_{sp} = 9.8 \times 10^{-11}$) in

a) water
b) 0.00050 mol/L $Al_2(SO_4)_3$
c) 0.00050 mol/L $BaCl_2$

If 50 mL of a saturated solution of $BaSO_4$ in water is evaporated to dryness, how much $BaSO_4$ will be left as a residue?

114) The $K_{sp}$ of AgCl is $1.8 \times 10^{-10}$. Will a precipitate form if 60 mL of a 0.10 mol/L solution of $AgNO_3$ is mixed with 40 mL of a 0.0010 mol/L solution of NaCl? Clearly show all the steps in your answer.

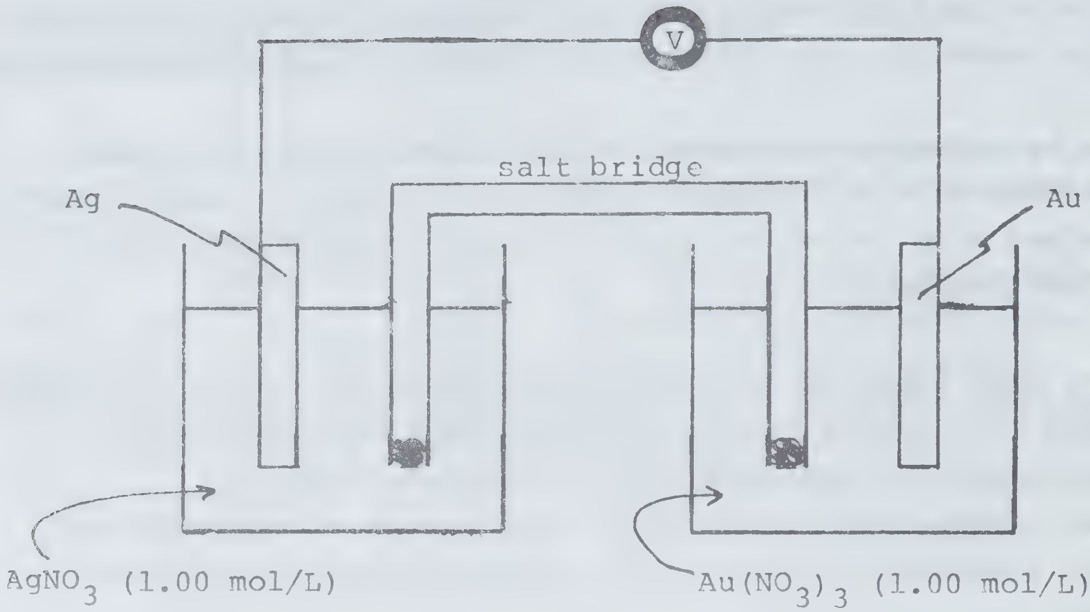
115) Determine the final concentration of all ions if 200 mL of a 0.1000 mol/L sodium iodide (NaI) solution is mixed with 300 mL of a 0.200 mol/L lead(II) nitrate, $Pb(NO_3)_2$, solution. It is known that the precipitate formed is lead(II) iodide, $PbI_2$.

116) Show by calculation whether or not a precipitate will form if 100 mL of a 0.0300 mol/L solution of sodium chloride (NaCl) is mixed with 200 mL of a 0.0200 mol/L solution of silver sulfate ($Ag_2SO_4$).

117) In an experiment an iron nail was wrapped in a strip of magnesium, placed in a petrie dish and covered with agar containing phenolphthalein and potassium hexacyanoferrate.
A nail wrapped in nickel strip was treated in the same way.
After a period of one day the following observations were made:
In the dish with the nail wrapped in magnesium the agar had a pink colour whereas in the dish with the nail wrapped in nickel the agar had both a pink colour and a blue colour.
In the appropriate spaces write the equations for the oxidation and reduction half reactions as well as the overall equation for each of the reactions.

| | Nail wrapped in Mg | Nail wrapped in Ni |
|---|---|---|
| Oxidation $\frac{1}{2}$ reaction | | |
| Reduction $\frac{1}{2}$ reaction | | |
| Overall reaction | | |

118)




You may use the table of standard reduction potentials for this question.

a) On the diagram clearly indicate

i) the direction of electron flow

ii) the anode

iii) the direction of cation movement

b) Answer the following questions in the spaces provided.

i) Write the equation for the cathode reaction.

ii) Write the overall net ionic equation.

iii) Which electrode decreases in mass?

iv) What is the maximum voltage that could be produced by this cell?

v) What happens to the voltage of this cell if $Cl^-$ ions are added to the silver half-cell?

119) Use oxidation numbers to balance the following equations. (Show all steps.)

a) $S^{2-} + Cr_2O_7^{2-} + H^+ \rightarrow S + Cr^{3+} + H_2O$

b) $KNO_2 + KMnO_4 + H_2SO_4 \rightarrow MnSO_4 + KNO_3 + K_2SO_4 + H_2O$

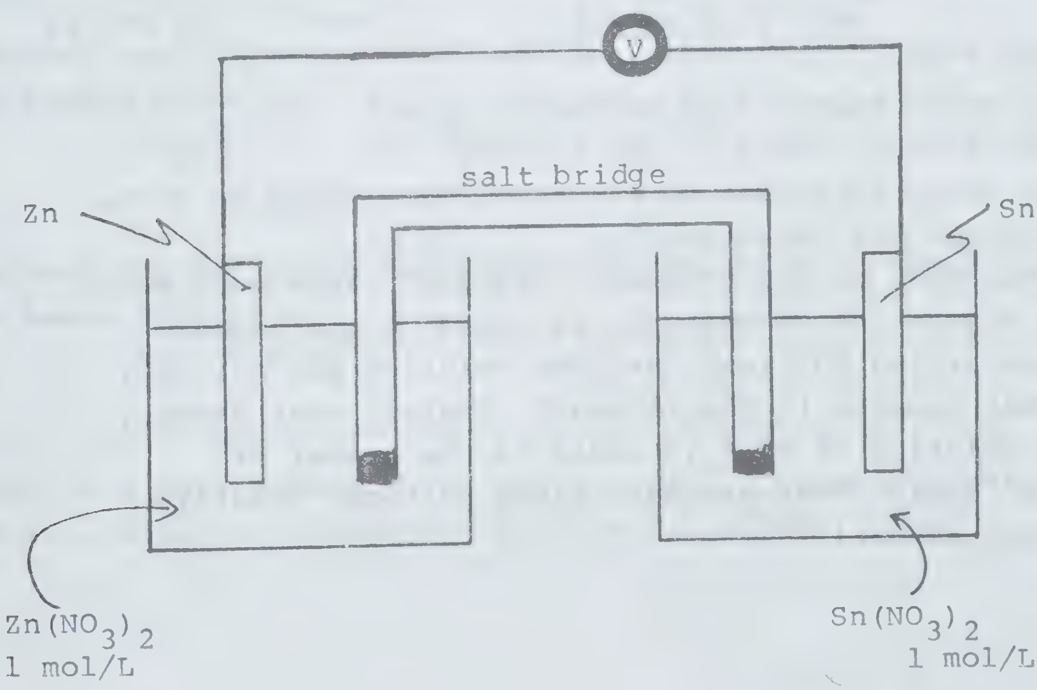
120) With reference to a table of $E^o$ values, determine what will happen when an iron spoon is used to stir a solution of $AlCl_3$. Explain your answers.

121) An electrochemical cell is to be made from a zinc rod in $Zn(NO_3)_2$ solution and a tin rod in $Sn(NO_3)_2$ solution.

a) On the accompanying diagram indicate the cathode, the anode, the direction of flow of the electrons and the direction of flow of positive ions.

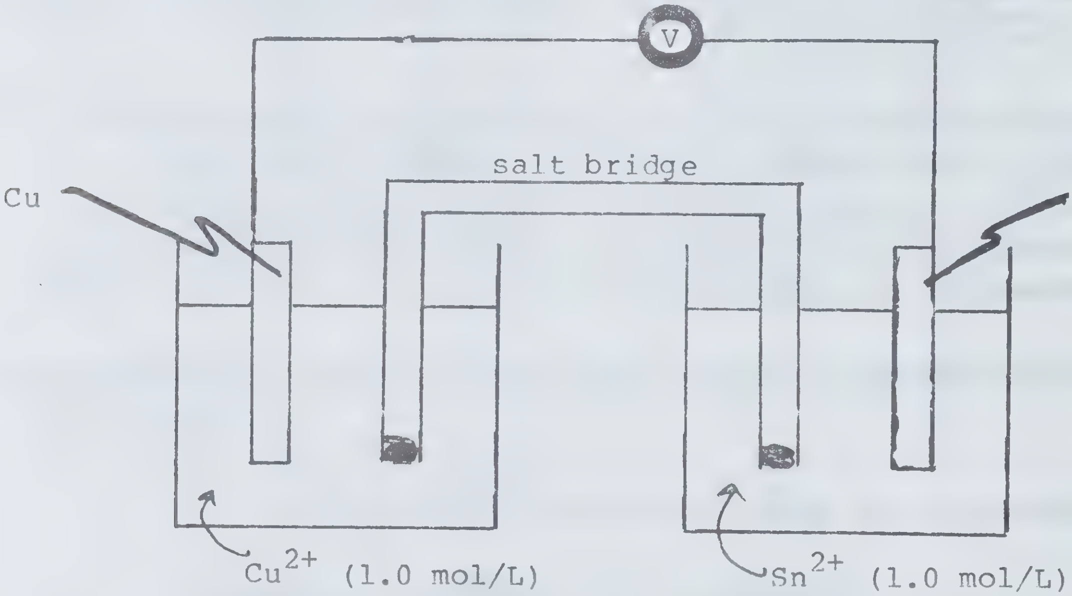
b) Write the equations for the half-reactions at each electrode.

c) Determine the standard voltage of this cell.



122) What external voltage would be required to reverse the direction of electron flow in the electrochemical cell formed between metallic copper dipping in an aqueous 1.0 mol/L $Cu^{2+}$ solution and metallic chromium dipping in an aqueous 1.0 mol/L $Cr^{3+}$ solution? Use a diagram to show how the positive and negative terminals of the external battery would be connected to this cell.

123)




a) In which beaker does oxidation occur?

b) Which metal strip is the cathode?

c) In which direction do electrons flow (draw an arrow through the voltmeter)?

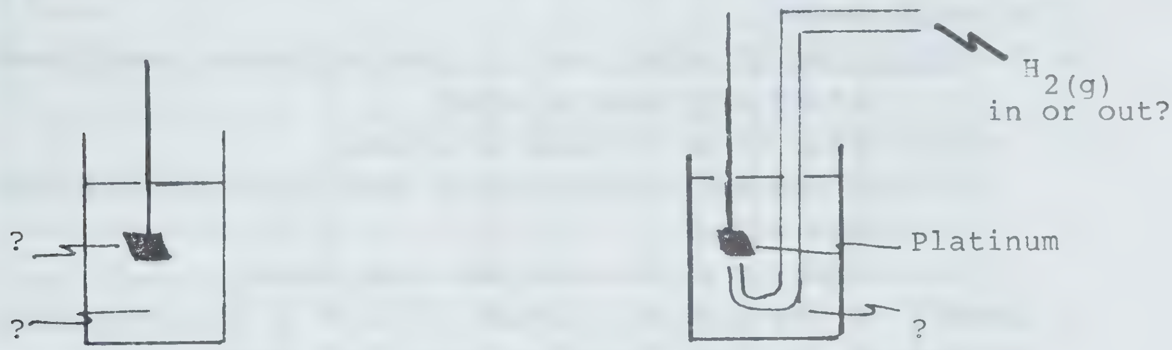
d) What will be the voltmeter reading? (Show your work)

e) A crystal of $Cu(NO_3)_2(s)$ is added to the beaker containing Cu2+(aq), and the solution was stirred. What happens to the voltage? Explain your answer.

f) A solution of $Na_2S$ is added to the beaker of $Sn^{2+}(aq)$. What happens to the voltage? Explain your answer.

124) Complete the following sketch to show how a cell would be set up to measure the standard half-cell potential ($E^o$) for the reaction

$Co^{2+}(aq) + 2e^- \rightarrow Co^o(s)$




Identify all the "?" on the diagram

125) For the electrolysis of fused (molten) $AlI_3$, using inert electrodes, write the equations for the anode and cathode reactions and classify them as oxidation or reduction. Name the products of the electrolysis.

126) Balance the following half-reaction, assuming it takes place in acidic solution:

$Cr_2O_7^{2-} \rightarrow 2Cr^{3+}$

127) Balance the following half-reaction, assuming it takes place in basic solution:

$Zn \rightarrow ZnO_2^{2-}$

128) HOCl is a weak acid with $K_a = 3.2 \times 10^{-8}$. Calculate the pH in a solution containing 0.077 mol/L of HOCl.

129) Exactly 50.0 mL of HOCl solution of unknown concentration was titrated with 0.100 mol/L NaOH. An end point was reached when 38.5 mL of the base was added. Calculate the molar concentration of the HOCl solution.

130) 30.0 mL of a $9.00 \times 10^{-2}$ mol/L acetic acid ($CH_3COOH$) solution is diluted to 100 mL with water and titrated with 0.100 mol/L NaOH.

a) Calculate the pH under each of the following conditions.
   (i) before any base is added.
   (ii) after 15 mL of base is added.
   (iii) at the equivalence point when 27 mL of NaOH has been added.
   (iv) after 32 mL of NaOH has been added.

b) Comment on the appropriateness of each of the following indicators for the titration described above

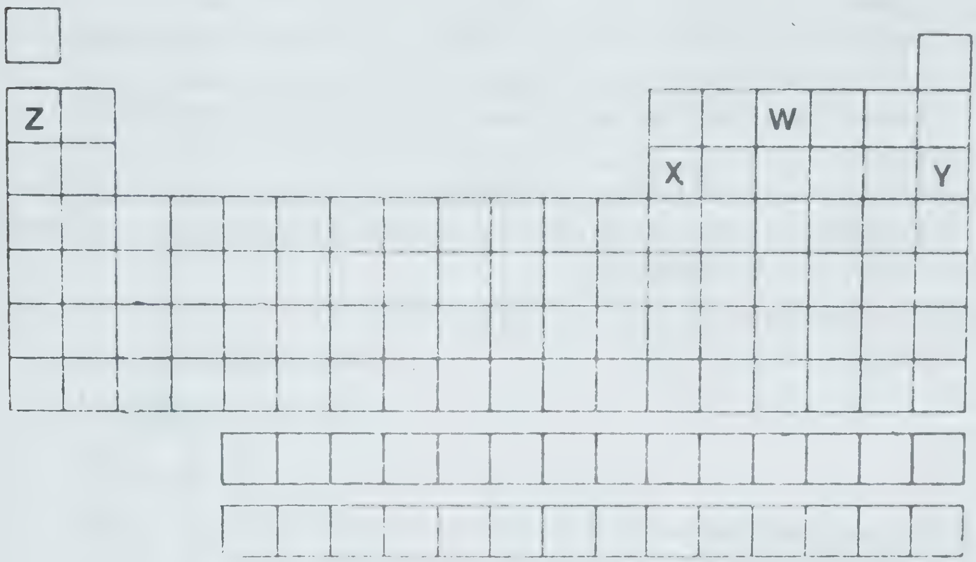
| Indicator | Colour Change | pH Range |
|---|---|---|
| methyl orange | red - yellow | 3.0 - 4.6 |
| litmus | red - blue | 4.5 - 8.3 |
| bromothymol blue | yellow - blue | 6.0 - 7.6 |
| phenolphthalein | colourless - red | 8.3 - 10.0 |
| alizarin yellow R | yellow - violet | 10.1 - 12.0 |

c) Account for the change in the indicator phenolphthalein from colourless to red as the solution becomes increasingly basic.

131) Account for the following using electron configurations:

(a) A vertical column in the periodic table constitutes a "chemical family".
(b) The ionization energy of boron is less than the ionization energy of beryllium.
(c) Carbon is a non-metal while lead, in the same family, is a metal.
(d) Fluorine is less metallic than chlorine.
(e) There are two possible valences for cobalt (Co).

132) Write the valence shell configurations and draw Lewis dot diagrams for each of the elements W, X, Y and Z shown on the outline of the Periodic Table.




133) Place the letters (A, B, C, D and E) in the appropriate places on the outline of the Periodic Table.

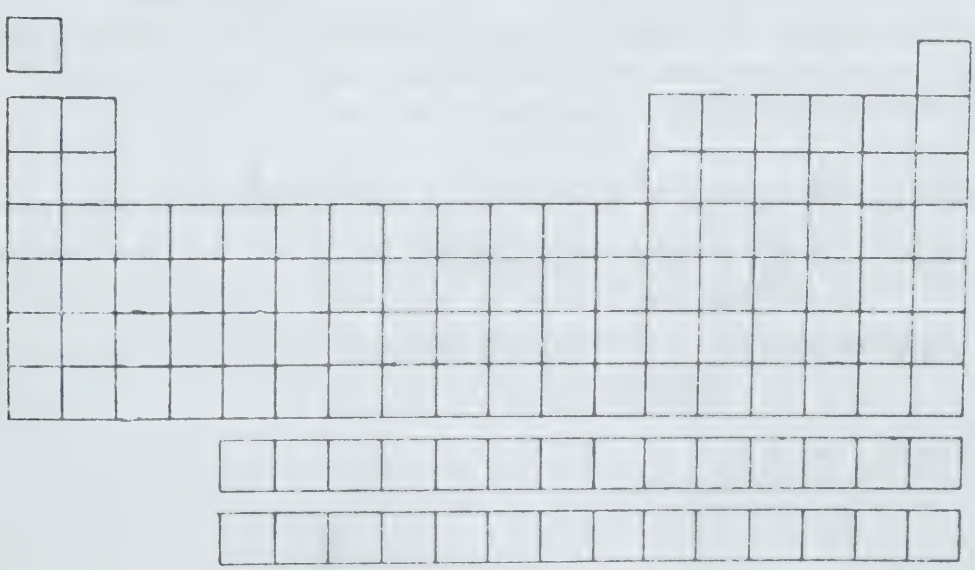
A - An alkali metal

B - An inert gas

C - An element that forms ions of the form $C^{2+}$

D - A transition element

E - An element that will displace copper from an aqueous $Cu^{2+}$ solution



134) Place the letters (A, B, C, D and E) in the appropriate places on the outline of the Periodic Table.

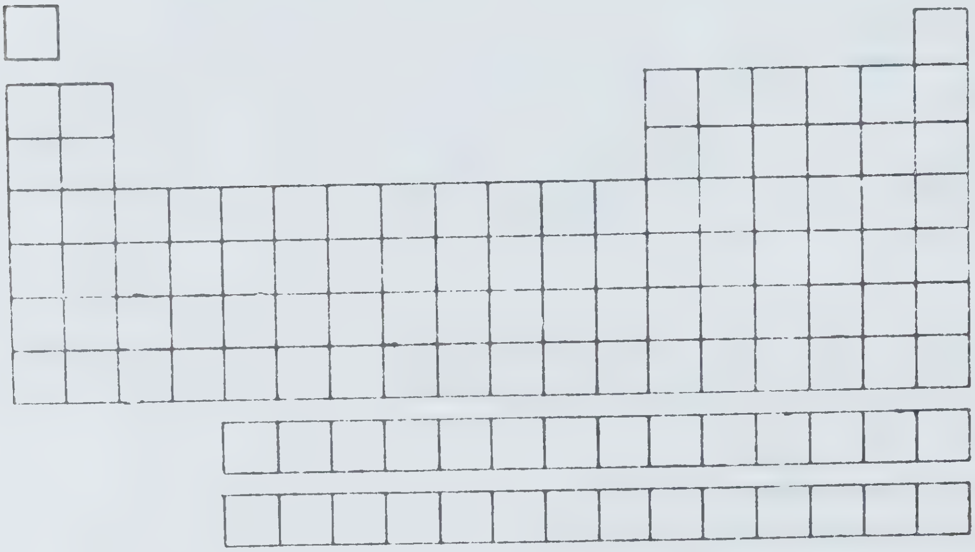
A - An element that has 2 valence electrons, both "3s" electrons.

B - An element with the outer shell electron configuration $4s^2 3d^{10} 4p_x^{\,1} 4p_y^{\,1}$

D C - An element which forms planar trigonal molecules with fluorine.

D - An element which forms tetrahedral molecules with hydrogen.

E - An element which has a first ionization energy greater than that of aluminum.



135) The heat of formation of butane, $C_4H_{10}$, is 135 kJ/mol. Determine the heat of reaction for the burning of butane gas in oxygen to produce carbon dioxide gas and liquid water. The balanced equation for the reaction is:

$$C_4H_{10}(g) + \frac{13}{2}\,O_2(g) \rightarrow 4\,CO_2(g) + 5\,H_2O(\ell)$$

$$\Delta H_f^\circ\,(CO_2(g)) = -393 \text{ kJ/mol}$$

$$\Delta H_f^\circ\,(H_2O(g)) = -90.7 \text{ kJ/mol}$$

136) Place the letters (A, B, C, D and E) in the appropriate places on the outline of the Periodic Table.

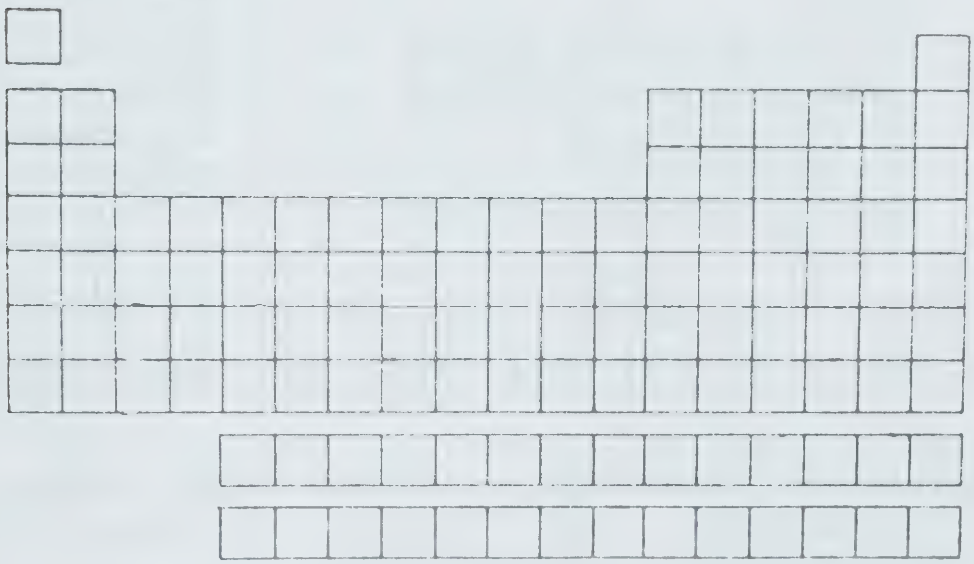
A - An element which combines with oxygen to form a covalent network solid.

B - An element which combines with oxygen to form a covalent molecular solid (at STP).

C - A metallic element which combines with chlorine to form an ionic solid.

D - An element which exists naturally as a covalent network solid.

E - A metallic element which is found naturally as an uncombined element.



137) The combustion of 0.044 g of propane, $C_3H_8$, raises the temperature of 100 g of water from 20.0$^{o}$C to 24.6$^{o}$C. The specific heat capacity of water is 4.18 J $g^{-1}$ $^{o}C^{-1}$. Calculate the enthalpy change (kJ/mol) for the combustion of propane.

138) Place the letters (A, B, C, D and E) in the appropriate places on the outline of the Periodic Table.

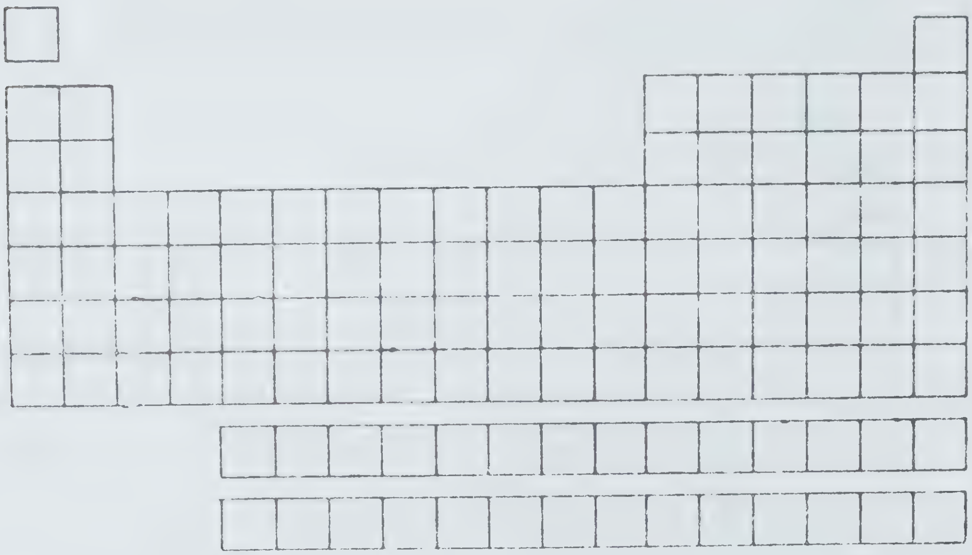
A - An element which is a stronger reducing agent than zinc.

B - A metallic ion which is a stronger oxidizing agent than $Ag^+(aq)$.

C - An element with 5 valence electrons.

D - A non-metallic element which exists in the form of ringed, 8-membered molecules ($D_8$).

E - An element which will displace bromine, $Br_2$, from an aqueous solution of bromide ion, $Br^-$.



139) Determine the value of $\Delta G$ at $25^oC$ and 101 kPa pressure for the reaction:

$$2HCl(g) + \frac{1}{2}\, O_2(g) \rightarrow H_2O(g) + Cl_2(g)$$

$\Delta H_f^o$ for HCl(g) is -92.5 kJ/mol. $\Delta S^o$ for the reaction is $-64.0\ J\ mol^{-1}\ K^{-1}$

140) Determine the value of $\Delta G$ at $25^{\circ}C$ and 101 kPa pressure for the reaction:

$$C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$$

$\Delta H_f^{\circ}$ for $C_2H_2(g)$ is + 223 kJ/mol. $\Delta S^{\circ}$ for the reaction is $-241\ J\ mol^{-1}\ K^{-1}$.

141) In a calorimetry experiment 40 mL of 0.50 mol/L HCl and 40 mL of 0.50 mol/L NaOH were mixed. The temperature rose from $10^{\circ}C$ to $15^{\circ}C$. Assume that the densities of all solutions were the same as pure water and that the specific heat capacities were also the same as pure water ($4.18\ J\ g^{-1}\ {}^{\circ}C^{-1}$). Calculate (show all steps):

a) the number of moles of NaOH used.
b) the amount of heat produced in the reaction.
c) the amount of heat liberated per mole of NaOH consumed.
d) the amount of heat produced if the same HCl solution had been mixed with 40 mL of 2.0 mol/L NaOH solution.

142) Given the equation for a reaction at $25^{\circ}C$ and 101 kPa pressure

$$4HCl(g) + O_2(g) \rightarrow 2H_2O(g) + 2Cl_2(g) + 113\ kJ$$

| $\Delta S^{\circ}$ values | | kJ $mol^{-1}\ K^{-1}$ | $\Delta H^{\circ}$ kJ/mol |
|---|---|---|---|
| $Cl_2(g)$ | = | 223.0 | 0.00 |
| $H_2O(g)$ | = | 188.7 | -241.8 |
| $HCl(g)$ | = | 186.8 | -92.30 |
| $O_2(g)$ | = | 205.0 | 0.00 |

a) What is $\Delta H_r^{\circ}$?

b) What is $\Delta S_r^{\circ}$?

c) What is $\Delta G_r^{\circ}$?

d) Above what temperature, on the Celsius scale, is the reaction spontaneous?

143) (a) The reaction $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ represents the formation of lime and carbon dioxide from calcium carbonate. Find $\Delta H_R^o$ for the reaction, using the data:

$\Delta H_f^o$ = $-635.5$ kJ/mol of $CaO(s)$

$\Delta H_f^o$ = $-393.5$ kJ/mol of $CO_2(g)$

$\Delta H_f^o$ = $-1207$ kJ/mol of $CaCO_3(s)$

(b) Is the value you calculated in part (a) of the question the value for $\Delta H_f^o$ of carbon dioxide? Explain in one or two sentences.

144) In a titration experiment 50 mL of 0.20 mol/L HCl neutralized (to the bromothymol blue end point) 10 mL of KOH solution. What is the concentration (mol/L) of the KOH solution?

145) Using equations determine whether aqueous solutions of the following compounds are acidic, basic or neutral:

| | | |
|---|---|---|
| (i) | calcium nitrate | $Ca(NO_3)_2$ |
| (ii) | sodium benzoate | $C_6H_5COONa$ |
| (iii) | sodium carbonate | $Na_2CO_3$ |
| (iv) | ammonium acetate | $NH_4CH_3COO$ |

146) A 10.0 g sample of a commercial washing powder, containing ammonium sulphate as one of the active ingredients, was treated with an excess of sodium hydroxide.

$(NH_4)_2SO_4 + 2NaOH \rightarrow 2NH_3 + Na_2SO_4 + 2H_2O$

The ammonia that formed was distilled into 50.0 mL of 0.250 mol/L $H_2SO_4$. The excess sulphuric acid was neutralized with 27.9 mL of 0.250 mol/L KOH. Calculate the percentage, by mass, of ammonium sulphate in the sample.

147) Methyl orange indicator turns from red to yellow in the pH range 3.2 to 4.4.
What colour is it in a 1.0 mol/L solution of boric acid ($K_a = 5.8 \times 10^{-10}$)? Show your reasoning.

148) Calculate the concentration of hydrogen ion in a solution made by mixing 100 mL of 1.00 mol/L HCl with 300 mL of 1.20 mol/L NaOH solution.

149) In an experiment to determine the $K_a$ of a hypothetical acid, HA, a 0.10 mol/L solution of the acid was found to have a pH of 4.0.
Calculate $K_a$ for the acid.

150) Calculate the $[H^+]$, $[OH^-]$, and pH of a solution containing 0.365 g of pure HCl in 100 mL of solution.

151) Calculate the $[H^+]$ in a solution of $CH_3COOH$ that contains 1.2 g of $CH_3COOH$ in 1000 mL of solution.
$K_a$ for $CH_3COOH = 1.8 \times 10^{-5}$.

152) $Al(OH)_3$ is an example of an "amphoteric" hydroxide. Explain what this means. Use equations to illustrate your answer.

153) Zinc hydroxide is an amphoteric hydroxide. Write equations for its reaction in aqueous solutions containing excess
a) $H^+$
b) $OH^-$
c) $NH_3$

154) Some food companies place sodium acetate ($NaCH_3COO$) on their potato chips. Use the chemistry of sodium acetate in saliva (a slightly acidic aqueous solution) to explain the effect this will have on the taste of the chips.

155) When used in titrations NaOH solutions are first made up to **approximate** concentrations and then standardised by titration against oxalic acid or potassium hydrogen phthalate. Why is the NaOH solution not made up accurately in the first place?

156) Explain, using three or four sentences and equations, why air must be kept out of standardised solutions of sodium hydroxide.

157) 24.3 mL of 0.0400 mol/L $H_2SO_4$ reacts completely with 35.0 mL of NaOH solution.
Calculate the concentration of the NaOH solution.

158) What volume of concentrated sulphuric acid solution (density 1.80 g/mL and 98.0% $H_2SO_4$, by mass) is required to prepare 10.5 L of 0.154 mol/L $H_2SO_4$ solution?

159) The heat of fusion of ice is 5.9 kJ/mol and that of a hypothetical form of ice in which there are no hydrogen bonds is 1.3 kJ/mol. Assuming that the energy of a hydrogen bond is 20 kJ/mol, determine what percentage of the hydrogen bonds in normal ice are broken during fusion.

160) Describe typical ionic solids under the headings:
- location of elements in the periodic table
- valence orbitals (and their occupancy) responsible for ionic bonding
- strength of bonding forces (low, medium, high)
- melting point expected (low, medium, high)
- two other properties.

161) You are given a sample of an unknown powder.
Describe three simple experiments that you could do which would enable you to decide whether the bonding in the compound is predominantly ionic, van der Waal's or covalent.

162) State all the types of bonds you would expect to find in the solid state (crystals) of each of the following substances:

a) $CO_2$ carbon dioxide
b) Si silicon
c) Mg magnesium

163) a) Calculate the energy contained in photons of light which have a frequency of $6.17 \times 10^{14}$ Hz (cycles per second).

b) In what region of the spectrum is this light found?

164)

$$\lambda = \frac{h}{mv}$$

State the meaning of this formula.

What concept of Bohr's was de Broglie attempting to explain when he suggested this formula?

What was de Broglie's main hypothesis?

165) How is the wave mechanical model of the atom more in agreement with the Heisenberg uncertainty principle than with the Bohr model?

166) Platinum (Z = 78) and zinc (Z = 30) have the same number of atoms per cubic centimetre. How would thin sheets of these elements differ in the way they scatter alpha particles? Explain.

167) Explain, in principle, how the mass spectrometer is able to separate

(i) ions with the same charge but different mass and

(ii) ions with the same mass but different charge.

If a sample of oxygen gas containing only $^{16}O$ and $^{17}O$ isotopes were analyzed, how many lines would appear in the mass spectrum?

Assume that only diatomic ions of charge +1 and +2 are detected by the mass spectrometer.

168) a) How does the spectrum of a hydrogen discharge tube differ from that of an incandescent lamp?

b) How did the discovery of the hydrogen spectrum lead to the concept of energy levels in the atom?

c) Why is the energy level at infinite separation the value of zero?

d) What is the concept of "stationary energy states"? Why did Bohr introduce this concept into his model of the atom?

169) What is the significance of an "atomic model"? Why do we refer to an atomic model rather than to a law?

170) Excited lithium atoms emit light of $\lambda$ = 700 nm when returning to the ground state.
Calculate the difference in the energy levels involved given:

$$c = 3.00 \times 10^{8} \text{ m/s}$$
$$h = 3.98 \times 10^{-13} \text{ kJ s mol}^{-1}$$

171) A radioactive element A with mass number 180 and atomic number 80, emits an alpha particle and changes to element B. Element B emits a beta particle and is converted to element C. Write nuclear equations for these changes using mass numbers and atomic numbers of the particles A, B and C. Which of the particles A, B and C, are isotopes of the same element?

172) Bromine-85 decays spontaneously to form krypton-85. An initial sample of 90 g of bromine is reduced to 2.85 g in exactly 15 min.

a) Determine the half-life of bromine-85.
b) Write an equation to represent the decay of bromine-85.
c) How long would it take for the activity of bromine-85 to be reduced by 90%?

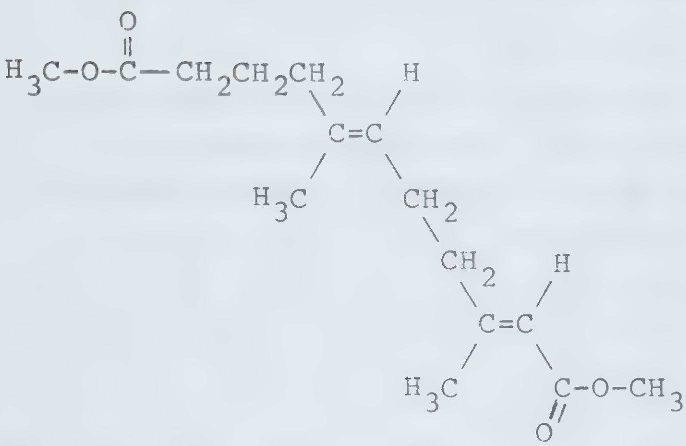
173) You are at dinner party and your host brings out a bottle of brandy for which he paid a great deal of money because he was told that it was bottled in the time of Napoleon (1769 - 1821). Since you are a research chemist, you are asked if there is any way in which the age of the brandy can be determined. You assert that tritium ($^{3}_{1}H$) dating is the way to do it. Ordinary water contains a very small amount of tritium that is formed in the earth's atmosphere by reactions involving cosmic rays. Tritium disintegrates by beta-emission at a rate equal to that at which it is formed. Water exposed to the atmosphere will contain a constant tritium content. Since brandy contains water, it should be possible to estimate its age. Since tritium in the bottle will not be replaced after it decays, the older the brandy, the lower its tritium content. You agree to test a sample of your host's brandy. You find that the sample has a tritium content of 30.6% of that of present-day water.
How long ago was the brandy bottled?

$$t_{1/2} \text{ for } ^{3}_{1}H = 12.3 \text{ years}$$

$$2.3 \log \left(\frac{N_o}{N}\right) = kt$$

174) The compound below was isolated from the "hairpencils" of 6500 male Monarch butterflies. (Hairpencils are extrusible brushlike structures in moths and butterflies that serve an active role during courtship.) How many geometrical isomers, including the one below are possible?
Draw the structure corresponding to each of the isomers.

(Consider rotation about the two carbon-carbon double bonds to be restricted.)



175) Represent the following information on a diagram. The activation energy of a reaction is 580 kJ/mol and the enthalpy change is -335 kJ/mol.

(i) Is the reaction exothermic or endothermic?

(ii) What is the activation energy of the reverse reaction?

(iii) Which reaction, the forward or reverse, would be favoured at the same conditions of temperature and concentration? Why?

176) a) At a given temperature it is found that $3.5 \times 10^{-4}$ g of silver chloride (AgCl) dissolves in $1.9 \times 10^{2}$ mL of solution to produce a saturated solution.
Calculate the $K_{sp}$ for silver chloride at the given temperature.

b) Would you expect the $K_{sp}$ for silver chloride to increase, decrease, or stay the same if temperature was increased? Account for your prediction.

177) The graph below illustrates the kinetic energy distribution for a gas in a closed container at two different temperatures.


a) Label the two axes of the graph.
b) Which line, A or B, represents the higher temperature?
c) How do the total areas under the curves compare?
d) Mark a line on the graph corresponding to the threshold energy of a slow reaction.
e) Use the above graph to account for the large effect a small temperature change has on the rate of a slow reaction.

178) For the reaction

$$6C(s) + 3H_2(g) + 49\ kJ = C_6H_6(\ell)$$

sketch a potential energy diagram and indicate on it:
a) $\triangle H_r$
b) the activation energy for the forward reaction
c) the pathway of a catalyzed reaction.

179) a) Explain what is meant by the terms "reaction mechanism" and "rate-determining step."
b) Using collision theory and the above terms, explain why increasing the concentration of a reactant does not necessarily increase the overall rate of a chemical reaction.

180) Consider the following reaction mechanism:

| | | | |
|---|---|---|---|
| $A + 2B$ | $\rightarrow$ | $2Z$ | slow |
| $2Z + B$ | $\rightarrow$ | $2K + N$ | fast |
| $K + A$ | $\rightarrow$ | $2X$ | fast |
| $K + 2X$ | $\rightarrow$ | $2Q$ | fast |

(i) Write the overall chemical equation for the reaction represented by this mechanism.

(ii) Write the rate expression (mathematicsl expression for rate calculations) for this reaction.

(iii) What effect would increasing the concentration of each of the following reagents have on the overall rate of reaction?

(a) increase [A]

(b) increase [B]

(c) increase [K]

Discuss each effect separately.

181) The following information describes five consecutive (with respect to atomic number) elements in the periodic table. Study the information so that you can identify the elements. Identify the elements and arrange them in order of increasing atomic number.

ELEMENT A - At room temperature, it is a non-toxic, diatomic highly unreactive gas. Under proper conditions it reacts with element B to form a compound with formula $AB_3$.

ELEMENT B - Element B is a highly toxic, diatomic gas at room temperature. Unlike element A, it is highly reactive and forms a compound with element C. This compound has the formula CB.

ELEMENT C - This element reacts vigorously with water to liberate a gas which ignites and burns.

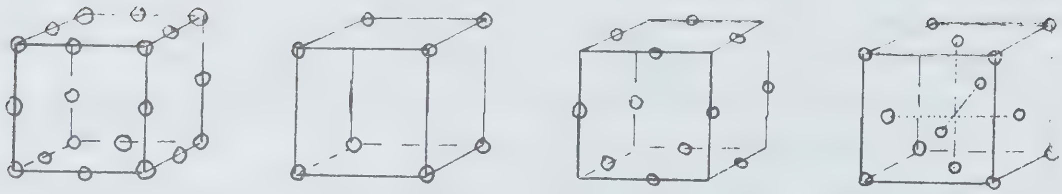
ELEMENT D - At room temperature this element exists as a highly unreactive monatomic gas. No compounds of this element have ever been reported.

ELEMENT E - This element exists at room temperature as a gaseous, non-toxic diatomic molecule. It reacts with element C to form the compound $C_2E$ and with hydrogen to form the compound $H_2E$.

# CHAPTER 11

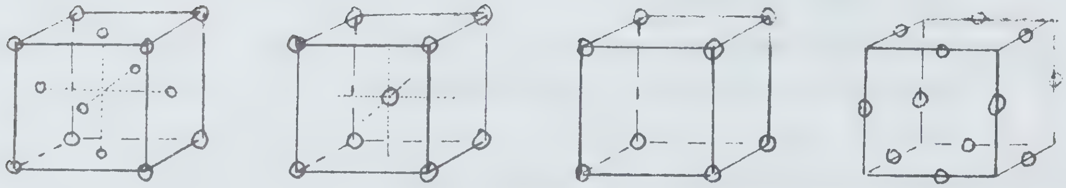
## DIAGRAMS FOR SELECTED INSTRUMENTS

D 1



I II III IV

D 2

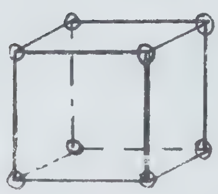


I II III IV

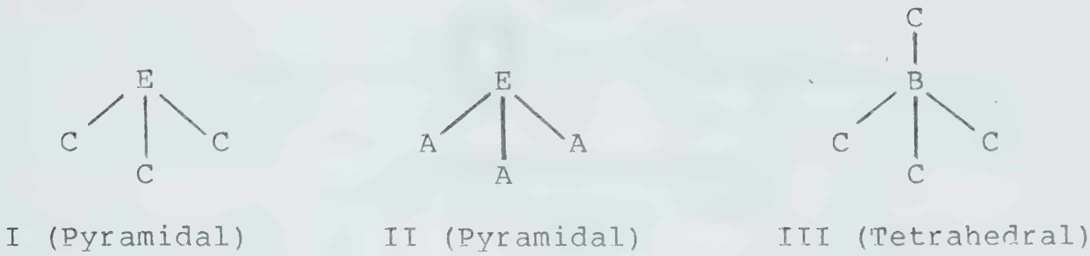
D 3

I II III IV

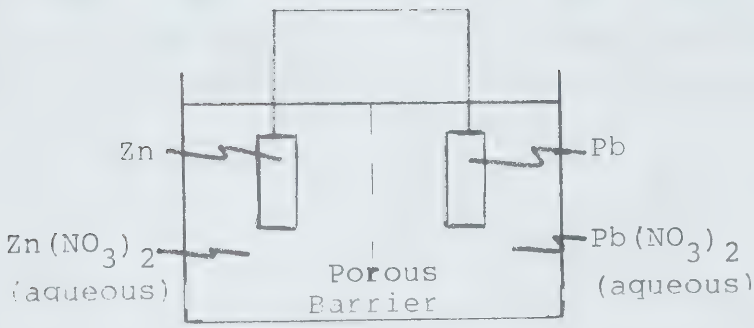
D 4



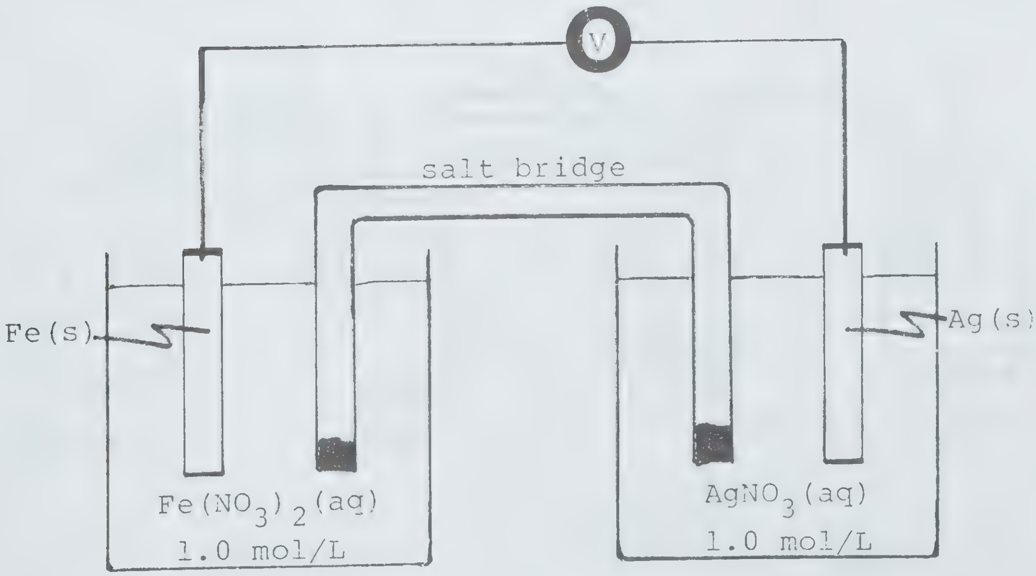
D 5


E
C
C
C
E
A
A
A
C
B
C
C
C
I (Pyramidal)
II (Pyramidal)
III (Tetrahedral)

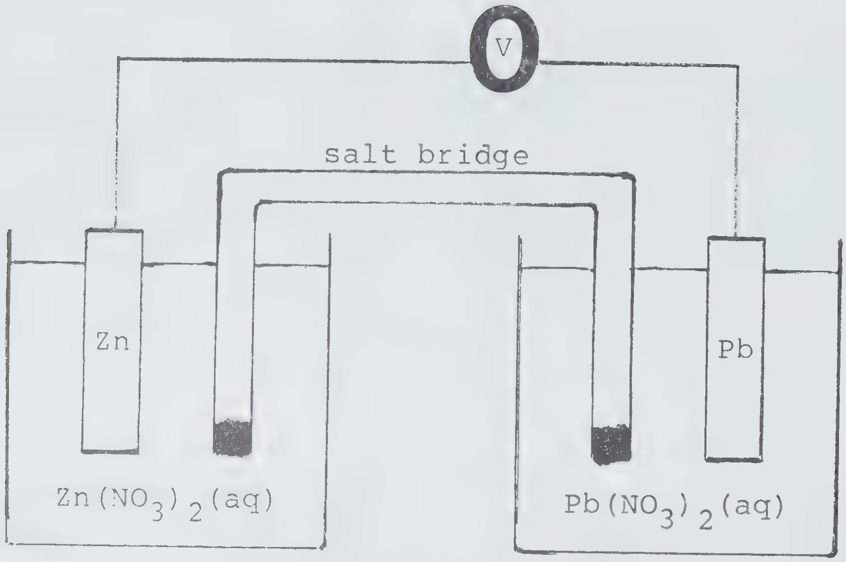
D 6


Zn
Pb
Zn(NO3)2
(aqueous)
Porous
Barrier
Pb(NO3)2
(aqueous)

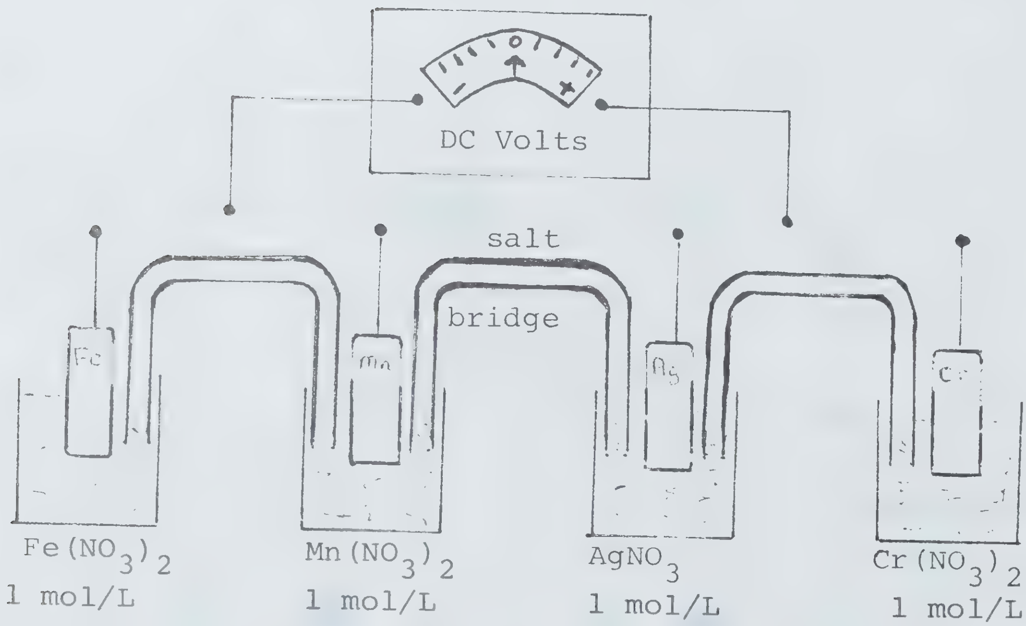
D 7


V
salt bridge
Fe(s)
Ag(s)
Fe(NO3)2(aq)
1.0 mol/L
AgNO3(aq)
1.0 mol/L

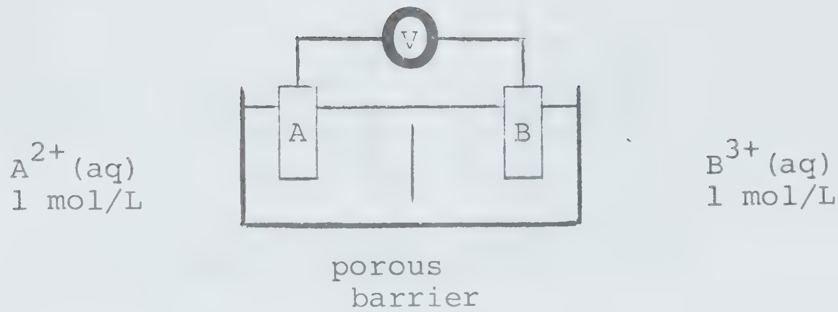
D 8


V
salt bridge
Zn
Pb
Zn(NO3)2(aq)
Pb(NO3)2(aq)

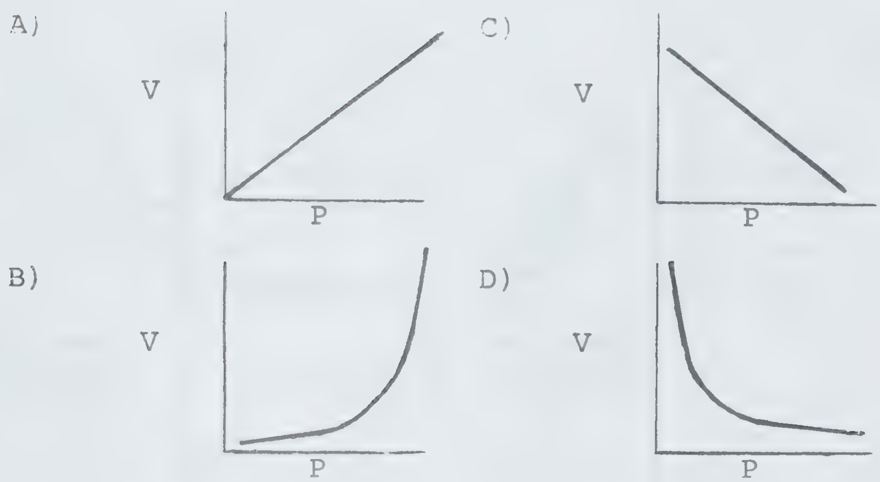
D 9


DC Volts
salt
bridge
Fe(NO3)2
1 mol/L
Mn(NO3)2
1 mol/L
AgNO3
1 mol/L
Cr(NO3)2
1 mol/L

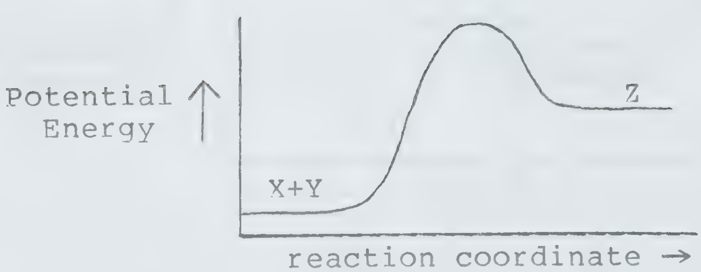
D 10


V
A
B
$A^{2+}$(aq)
1 mol/L
$B^{3+}$(aq)
1 mol/L
porous
barrier

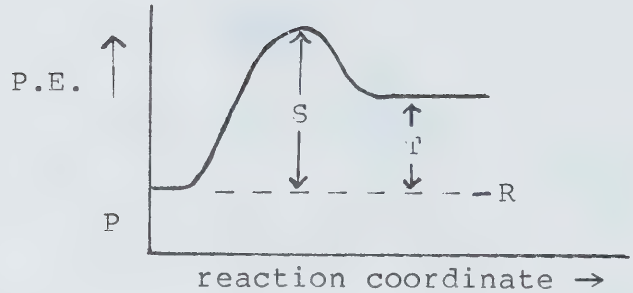
D 11


A)
V
P
C)
V
P
B)
V
P
D)
V
P

D 12

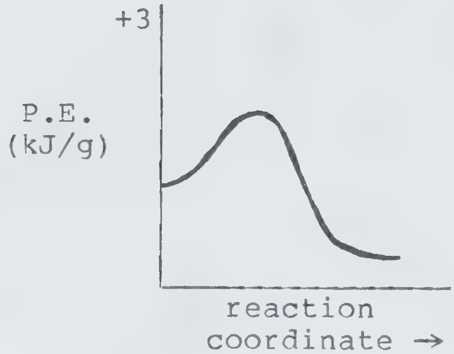

Potential
Energy
X+Y
Z
reaction coordinate →

D 13

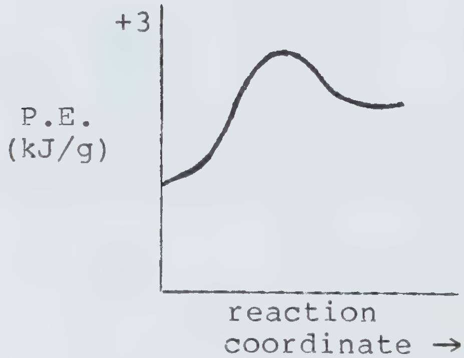



D 14

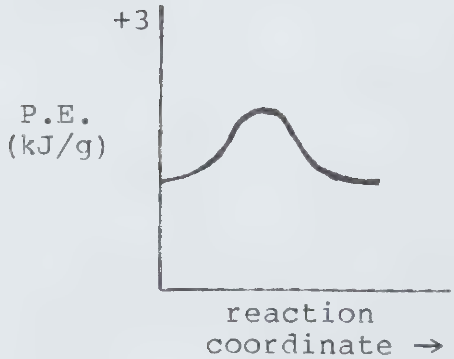
A)



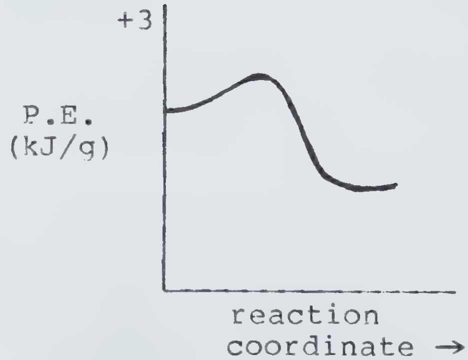

*C)



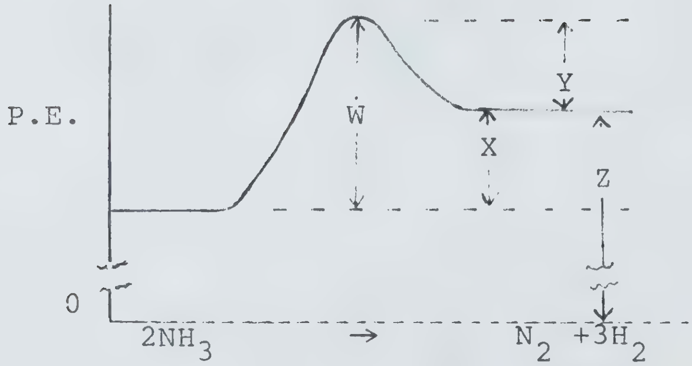

B)



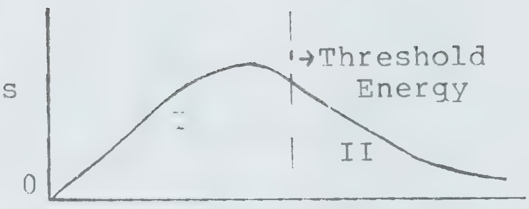

D)



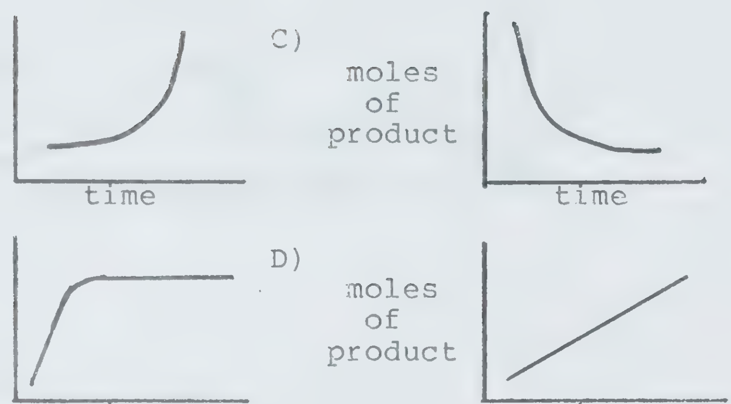

D 15



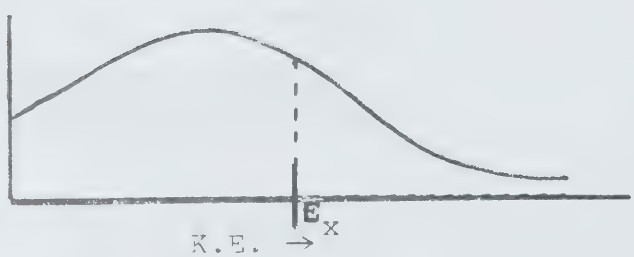
D 16



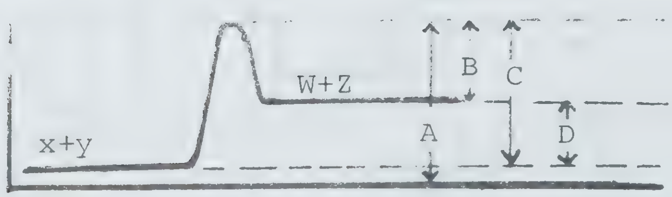

D 17



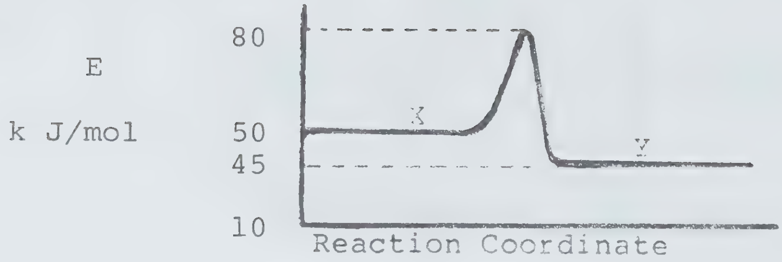

D 18




D 19

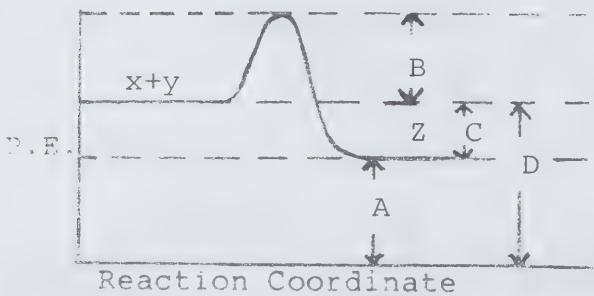


D 20

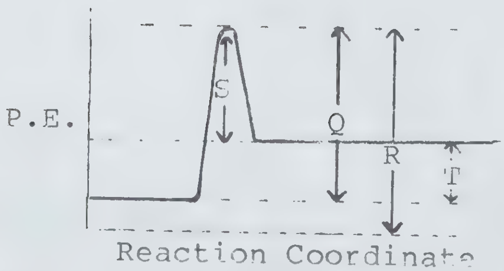



D 21

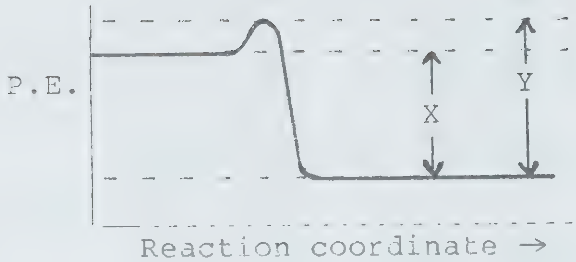

D 22



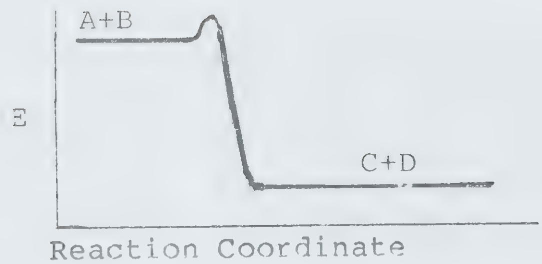

D 23



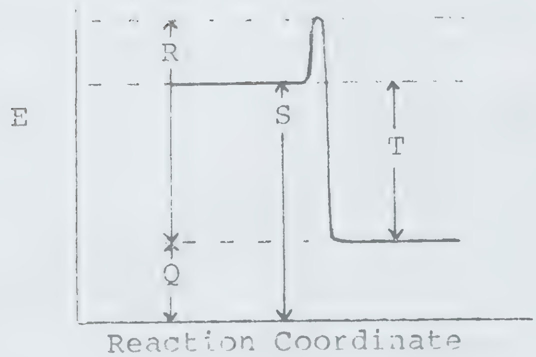
D 24



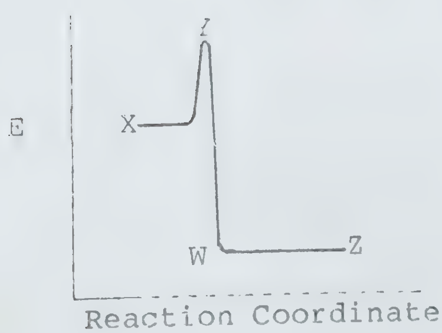

D 25




D 26




D 27



D 29

| | | | | | | |
|---|---|---|---|---|---|---|
| A) | ↑ | ↑ | ↑ | ↑ | ↑ | |
| | 1s | 2s | $2p_x$ | $2p_y$ | $2p_z$ | |
| B) | ↑↓ | ↑↓ | ↑ | ↑ | ↑ | ↑↓ |
| | 1s | 2s | $2p_x$ | $2p_y$ | $2p_z$ | 3s |
| C) | ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑↓ | |
| | 1s | 2s | $2p_x$ | $2p_y$ | $2p_z$ | |
| D) | ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑ | |
| | 1s | 2s | $2p_x$ | $2p_y$ | $2p_z$ | |

D 30

| | | | | | | |
|---|---|---|---|---|---|---|
| A) | N | ↑↓ | ↑↓ | ↑↓ | ↑ | __ |
| B) | Li | ↑↓ | ↑↓ | ↑ | __ | __ |
| C) | O | ↑↓ | ↑↓ | ↑↓ | ↑ | ↑ |
| D) | Ne | ↑↓ | ↑↓ | ↑ | ↑ | ↑ |

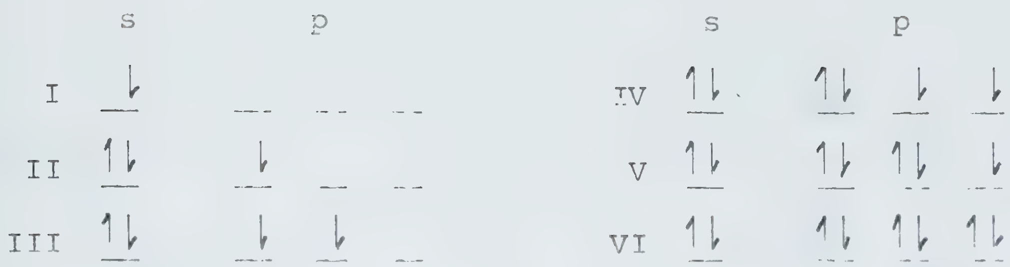
D 31

| | s | p | | |
|---|---|---|---|---|
| I | ↓ | __ | __ | __ |
| II | ↑↓ | ↓ | __ | __ |
| III | ↑↓ | ↓ | ↓ | __ |
| IV | ↑↓ | ↑↓ | ↓ | ↓ |
| V | ↑↓ | ↑↓ | ↑↓ | ↓ |
| VI | ↑↓ | ↑↓ | ↑↓ | ↑↓ |

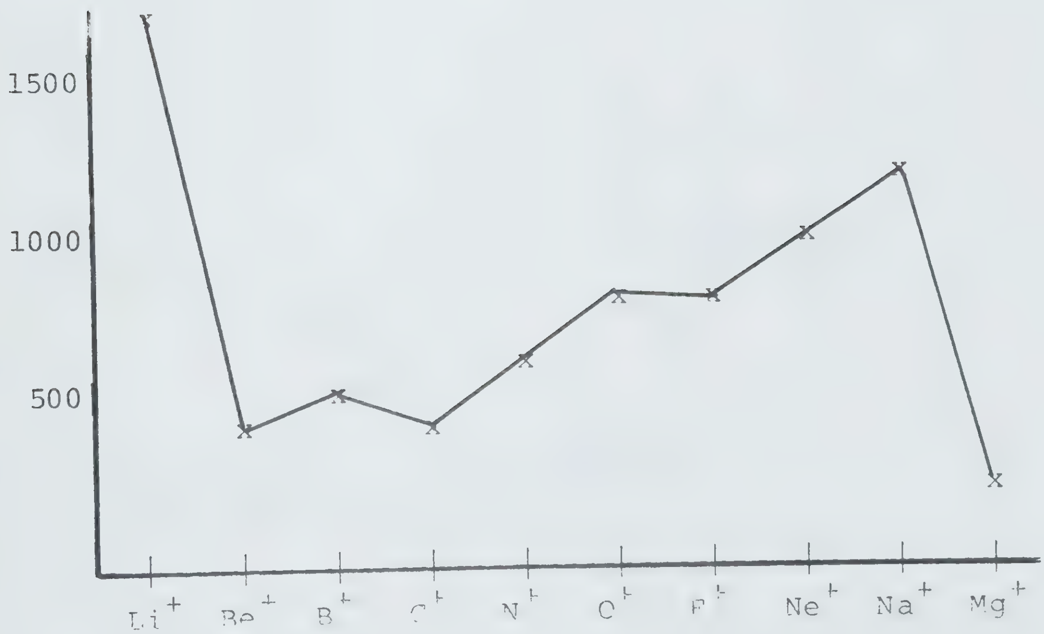
D 32

| | | 4d | | | | | 5s | 5p | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A) | $[_{36}Kr]$ | ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑ | | | |
| B) | $[_{36}Kr]$ | ↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑ | ↑↓ | | | |
| C) | $[_{36}Kr]$ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| D) | $[_{36}Kr]$ | ↑ | ↑ | ↑ | ↑ | ↑ | ↑↓ | ↑ | ↑ | ↑ |

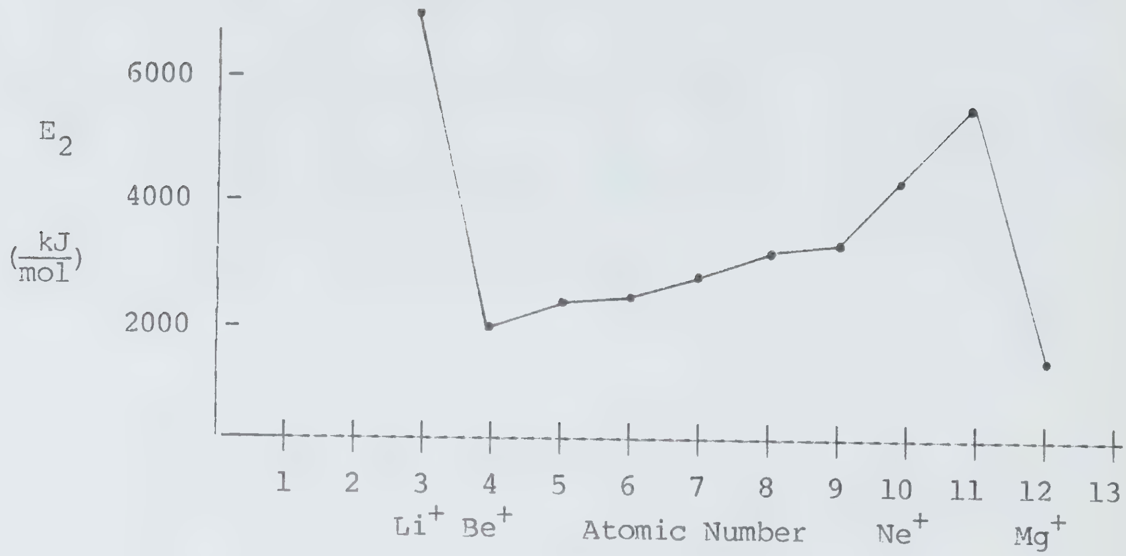
D 33



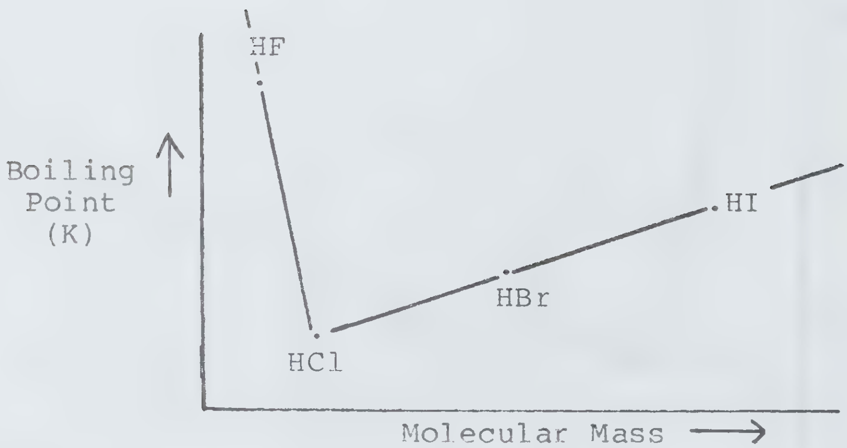

D 34



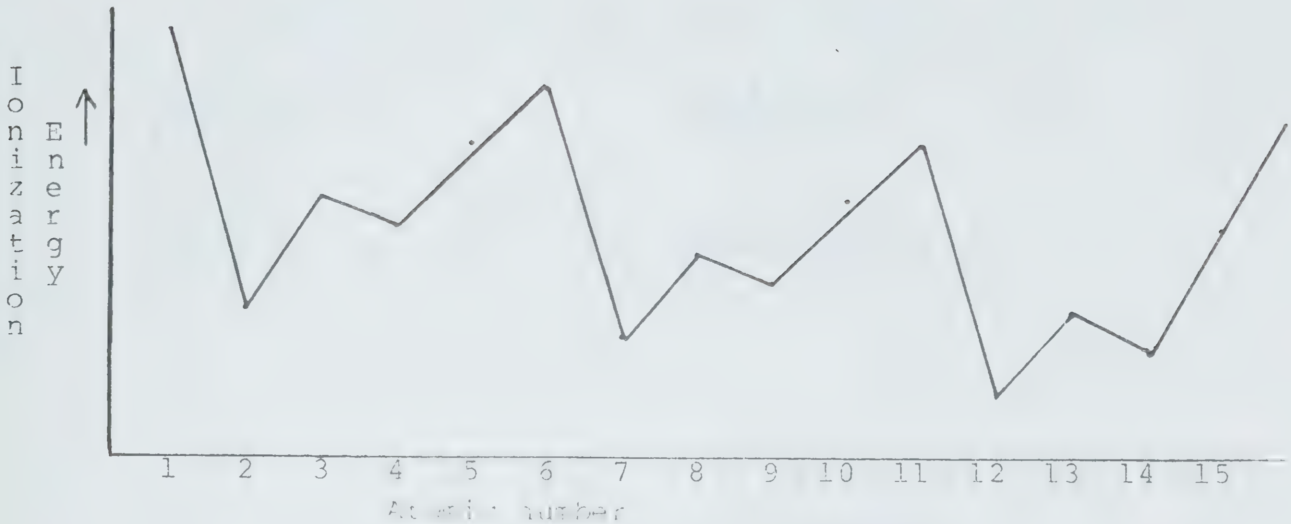
D 35


6000
4000
2000
$E_2$
$(\frac{kJ}{mol})$
1 2 3 4 5 6 7 8 9 10 11 12 13
$Li^+$ $Be^+$
Atomic Number
$Ne^+$
$Mg^+$

D 36


HF
HCl
HBr
HI
Boiling Point (K)
Molecular Mass

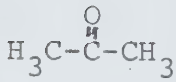
D 37


Ionization Energy
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

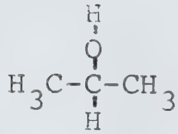
D 38

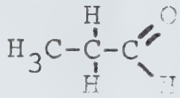

Ionization Energy
1
2
3

D 39

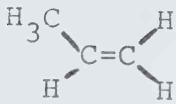
A) 

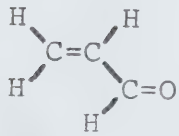
B) $H_3C-O-CH_3$

C) 

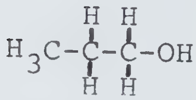
D) 

D 40

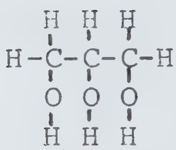
I) 

II) 

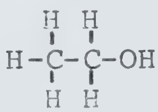
III) $H-C\equiv C-CH_3$

IV) 

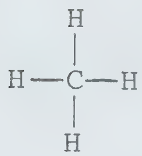
D 41

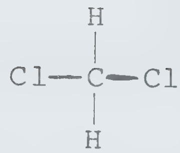


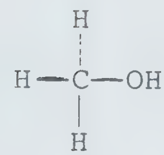
is far more viscous than ethyl alcohol

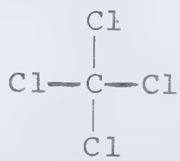


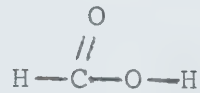
D 42

I) 

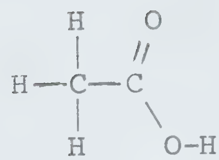
II) 

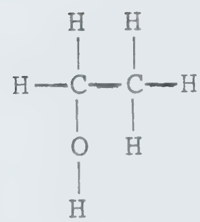
III) 

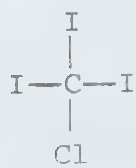
IV) 

V) 

D 43

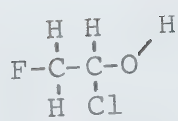
I) 

II) 

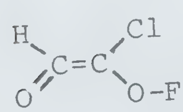
III) 

IV) 

D 44

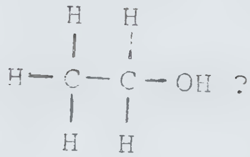
A) 

B) F-N=N-H

C) 

D) N≡N

D 45

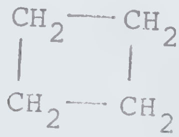


D 46

I $CH_3CH_2CH_2CH_3$

II $CH_3CH=CHCH_3$

III $CH_3C\equiv CCH_3$

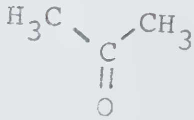
IV 

D 47

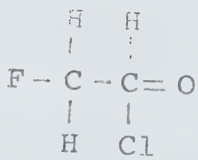
A) $H-F$

B) $O=C=O$

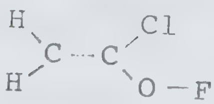
C) 

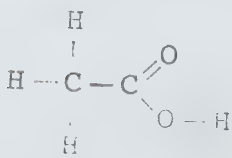
D) 

D 48

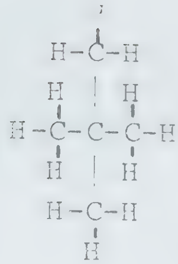
A) 

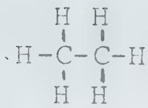
B) $H-F-N\equiv N-H$

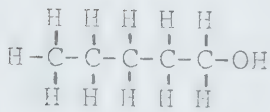
C) 

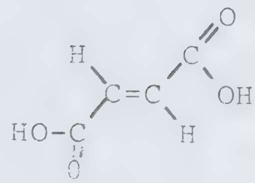
D) 

D 49

A) 

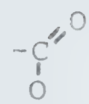
C) 

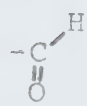
B) 

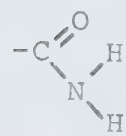
D) 

D 50

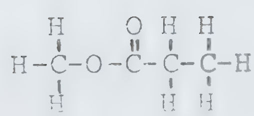
A) 

C) 

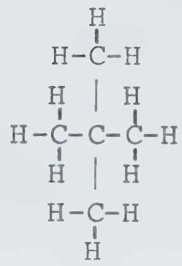
B) 

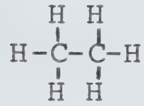
D) 

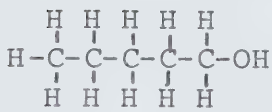
D 51

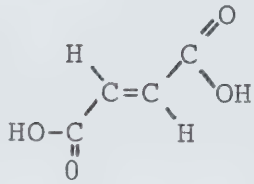
5) The ester  is called

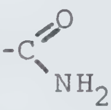
D 52

A) 

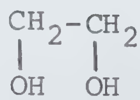
C) 

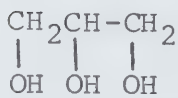
B) 

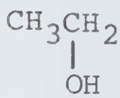
D) 

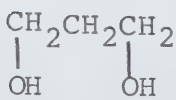
D 53 3) The structural formula-  is representative of an

D 54

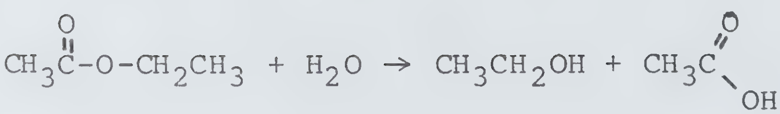
A) 

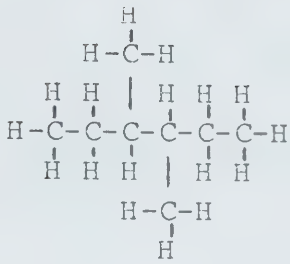
B) 

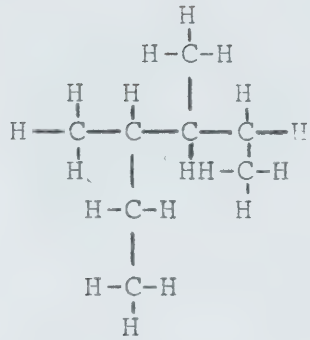
C) 

D) 

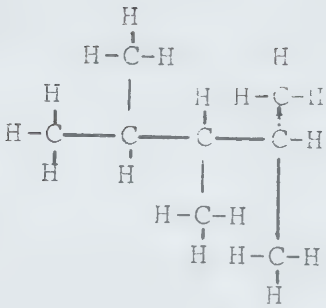
D 55

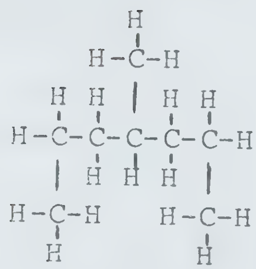


A) 

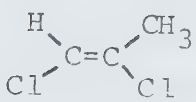
C) 

D 56

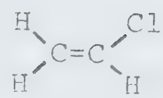
B) 

D) 

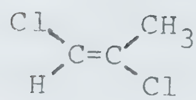
D 57



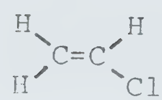
I



II

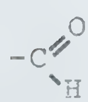


III

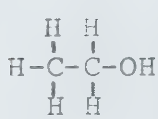


IV

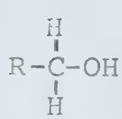
D 58

11)  is the functional group of

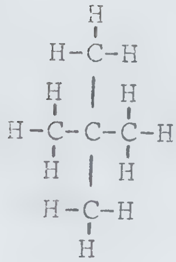
D 59

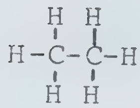
formula ?

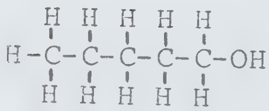
D 60

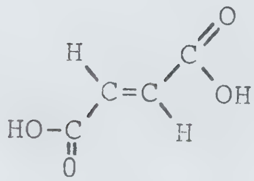
formula ?

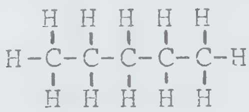
D 61

A) 

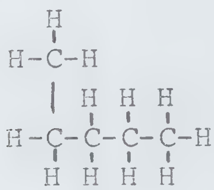
C) 

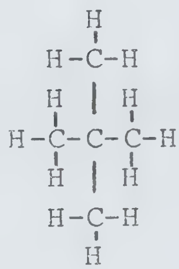
B) 

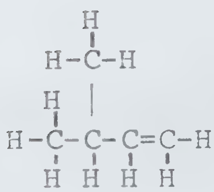
D) 

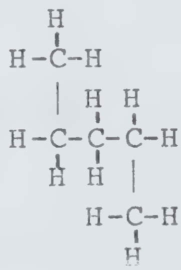
10) Which of the following is a structural isomer of  (n-pentane)?

D 62

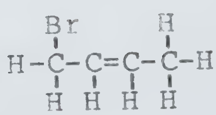
A) 

C) 

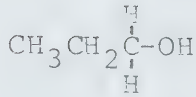
B) 

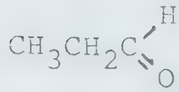
D) 

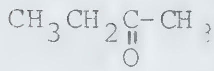
D 63

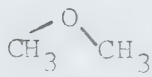
11) The name of the compound  is

D 64

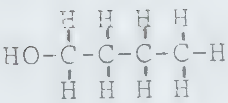
A) 

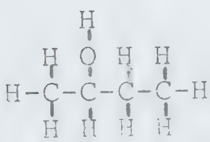
B) 

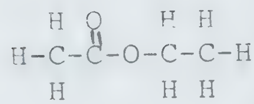
C) 

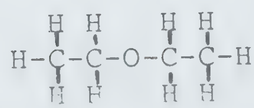
D) 

D 65

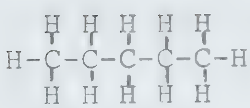
I) 

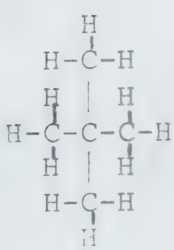
II) 

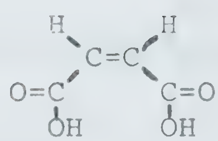
III) 

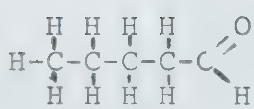
IV) 

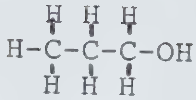
D 66

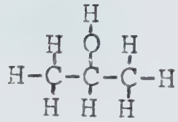
I) 

II) 

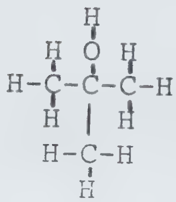
III) 

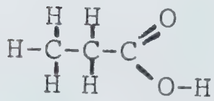
IV) 

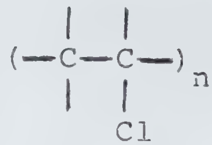
A) 

C) 

D 67

B) 

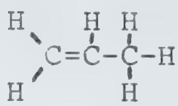
D) 

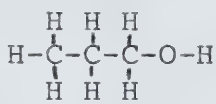
9) Polyvinyl chloride  is

D 68

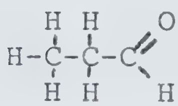
A) an addition polymer
B) a condensation polymer
C) a polyamide
D) a polyester

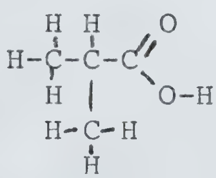
The following structural formulae refer to questions 10, 11 and 12

I) 

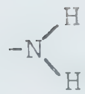
III) 

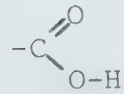
D 69

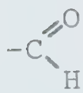
II) 

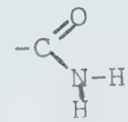
IV) 

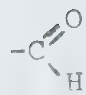
D 70

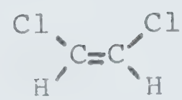
A) 

C) 

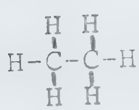
B) 

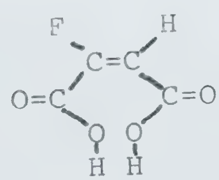
D) 

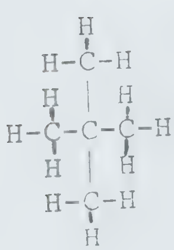
D 71 6) The functional group  is found in all

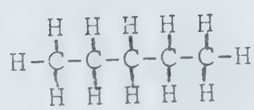
D 72 7) The correct name for the compound  is

D 73

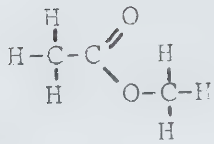
A) 

C) 

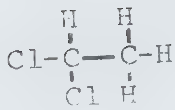
B) 

D) 

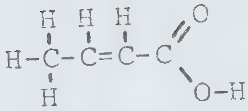
D 74

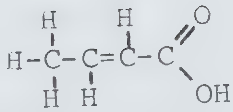


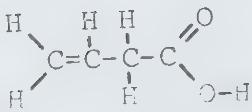
D 75

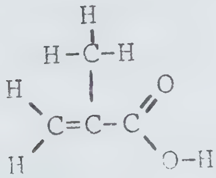


D 76

I 

III 

II 

IV 

D 77

11) The bond $-\overset{\overset{O}{\|}}{C}-O-$ is

D 78

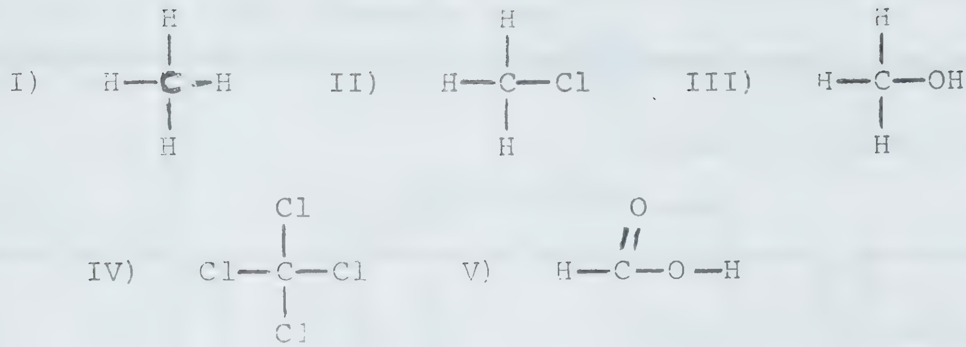
A) $CH_3CH_2CHO$

B) $CH_3CH_2\underset{\underset{O}{\|}}{C}CH_3$

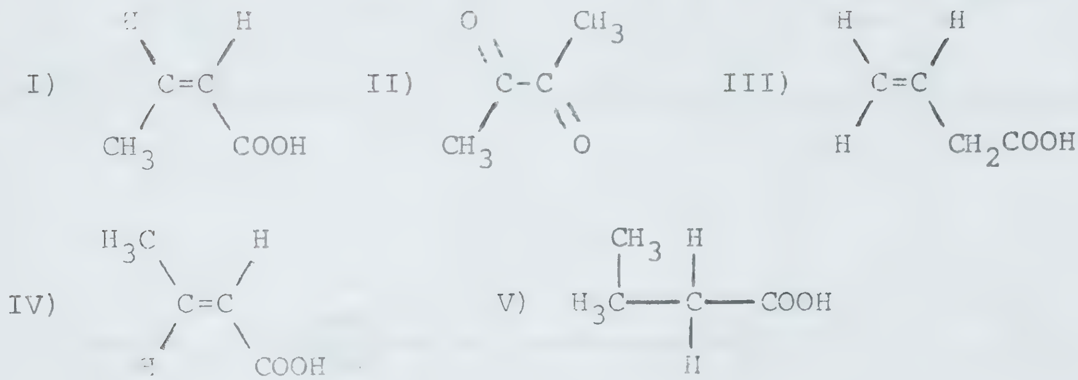
C) $CH_3CH_2COOH$

D) $CH_3OCH_3$

D 79



D 80

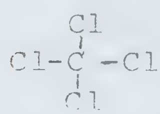


D 81

A) H-Cl

B) O=C=O

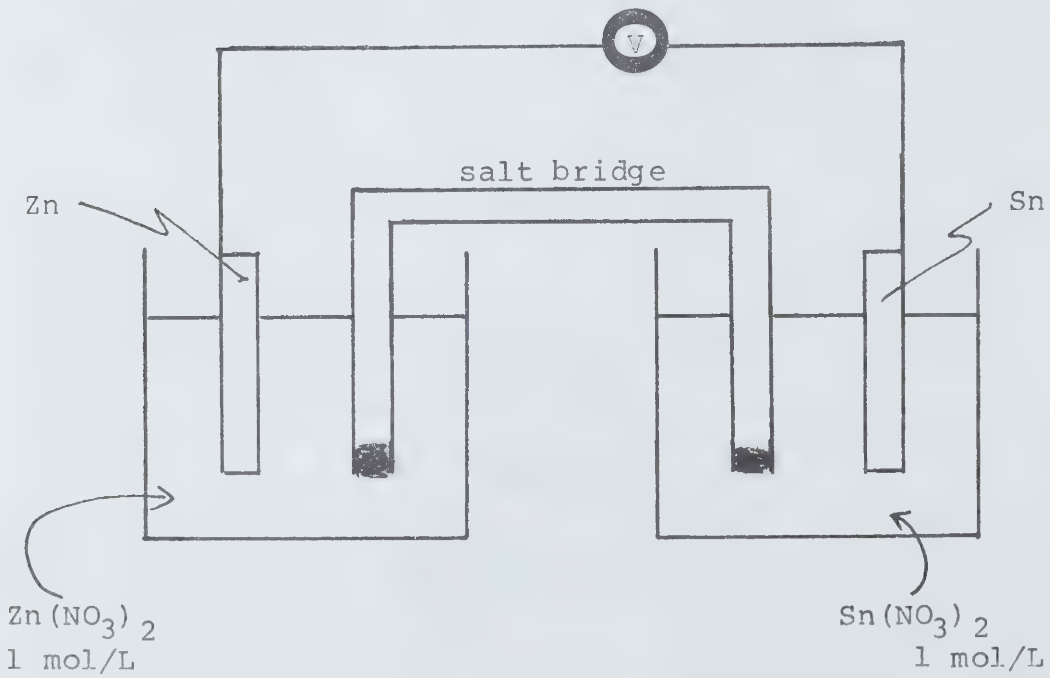
C) N≡N

D) 

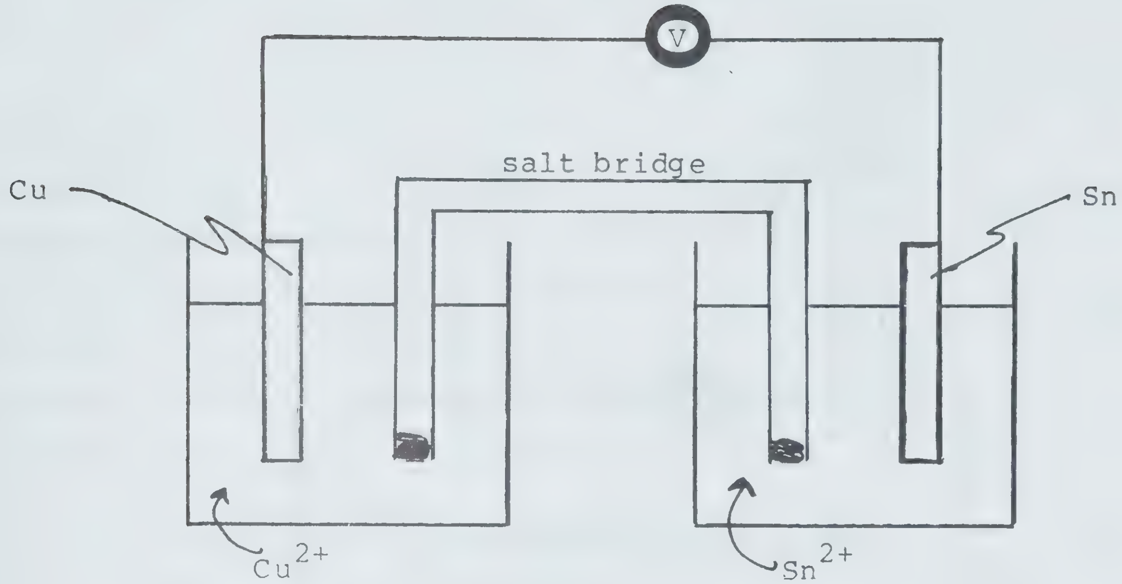
D 82

| | Nail wrapped in Mg | Nail wrapped in Ni |
|---|---|---|
| Oxidation $\frac{1}{2}$ reaction | | |
| Reduction $\frac{1}{2}$ reaction | | |
| Overall reaction | | |

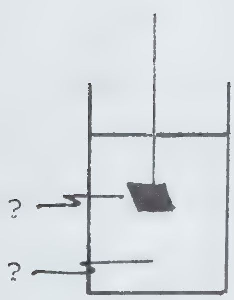
D 83

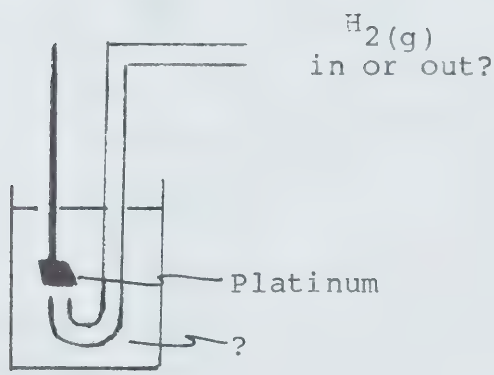


D 84

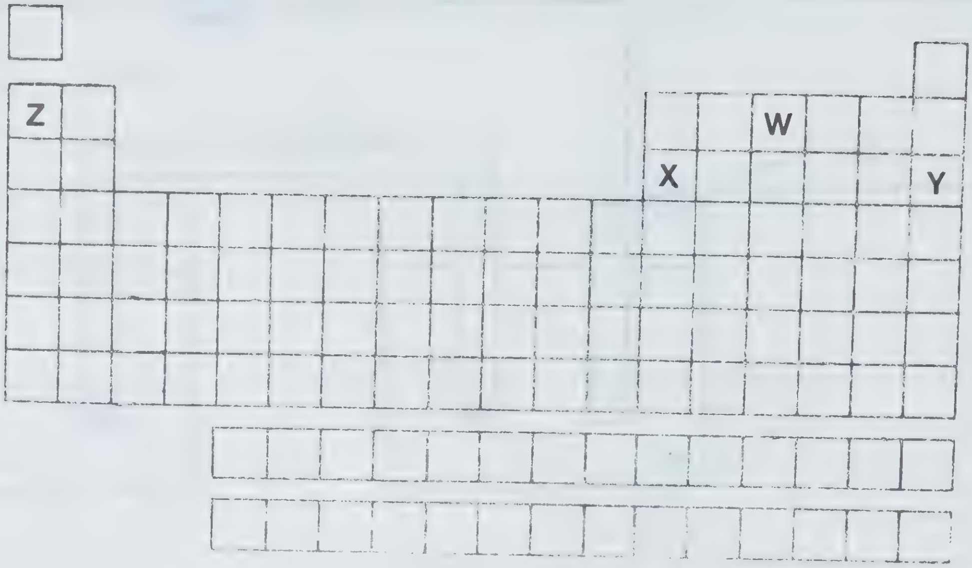



D 85

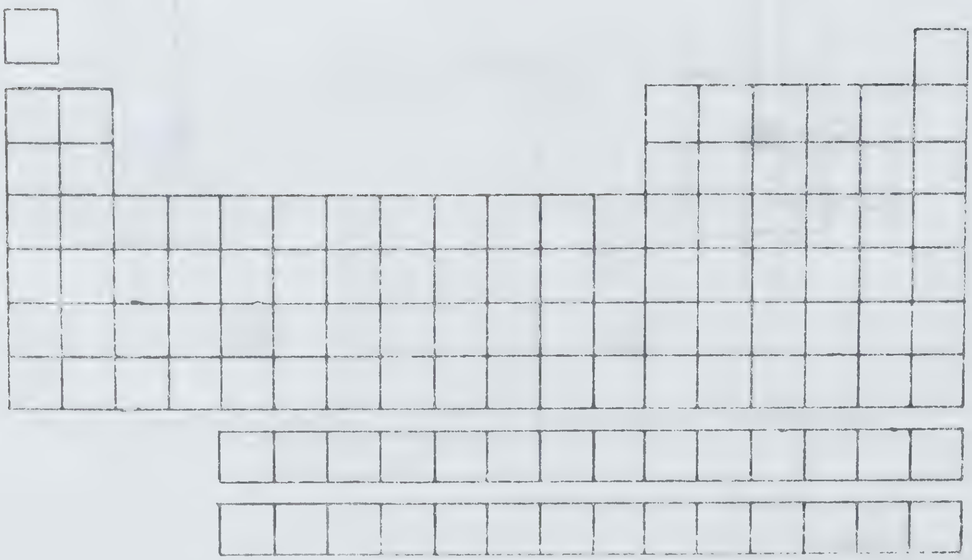


D 86



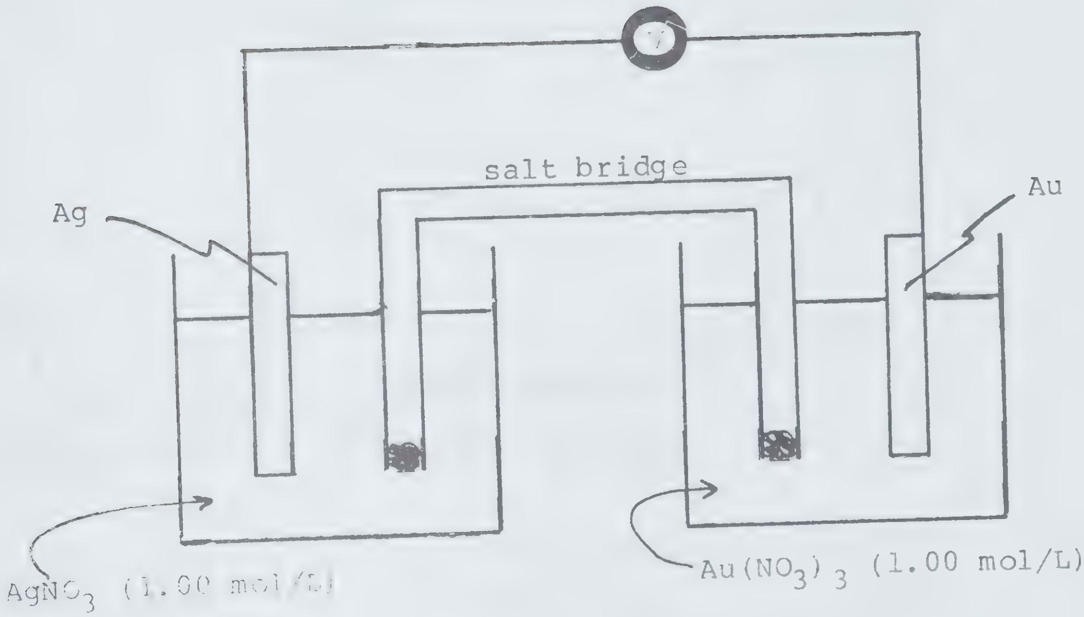

D 87



D 88 $\lambda = 7000\ A^{\circ}$

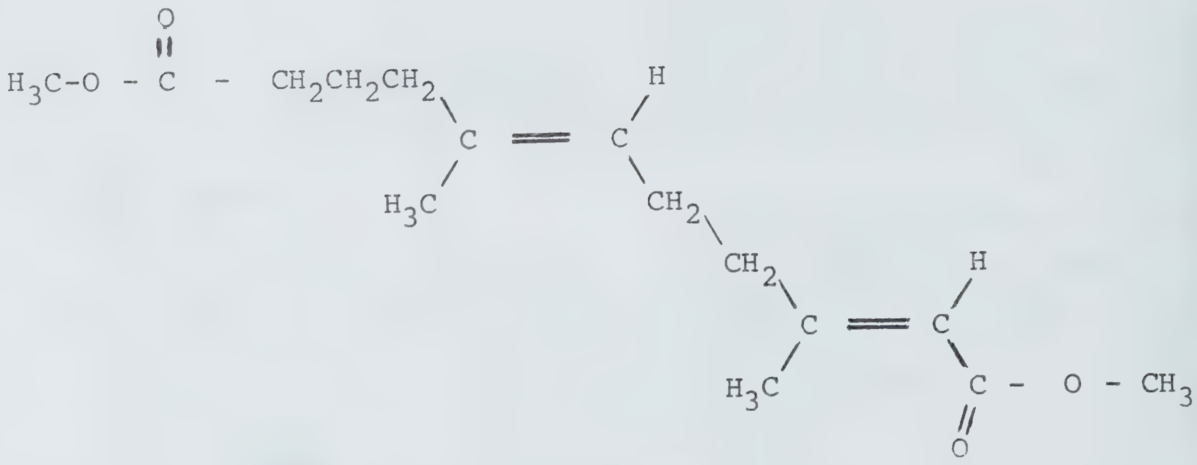
D 89 $\lambda = \dfrac{h}{mv}$

D 90

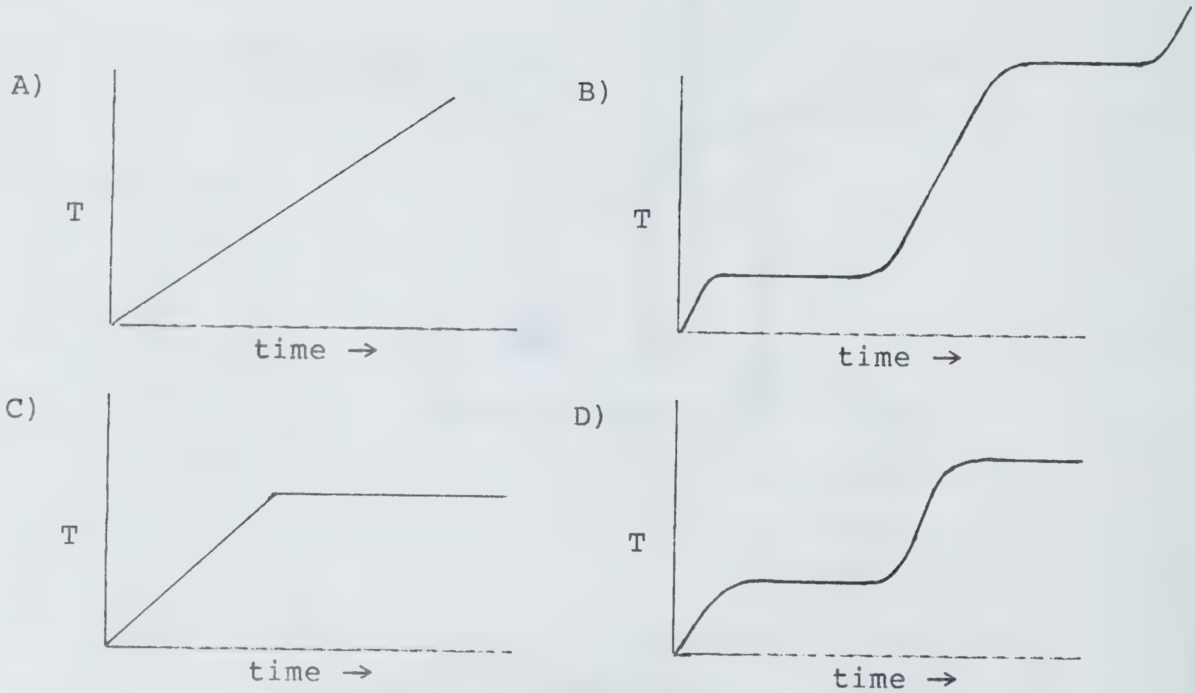



D 91

D 92

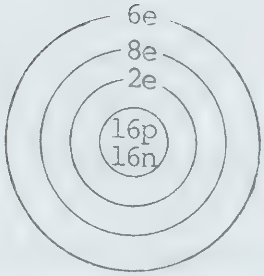


D 93

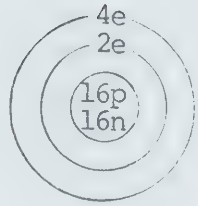


D 94

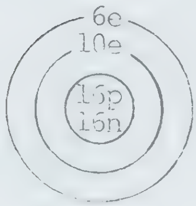
A)



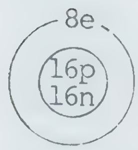

B)



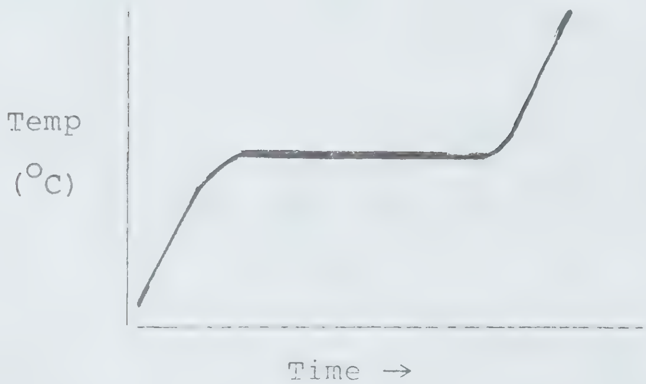

C)




D)

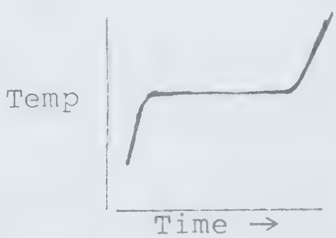



D 95

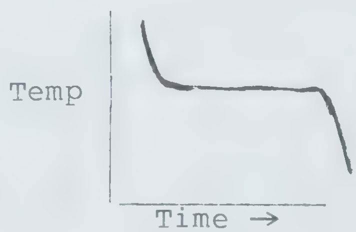



Which of the following graphs best represents the solidification of tin?

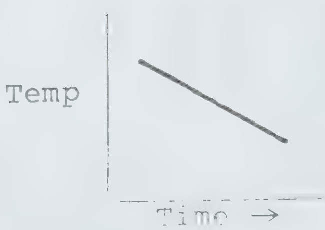
A)



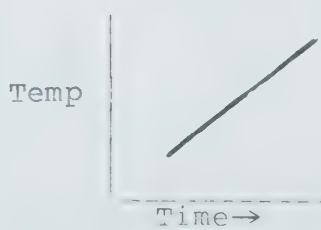

C)




B)



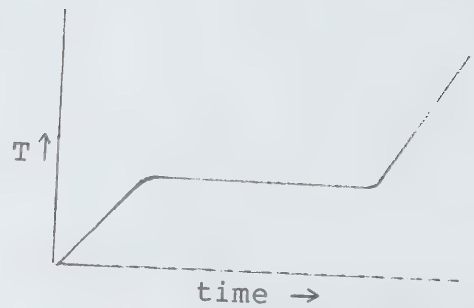

D)



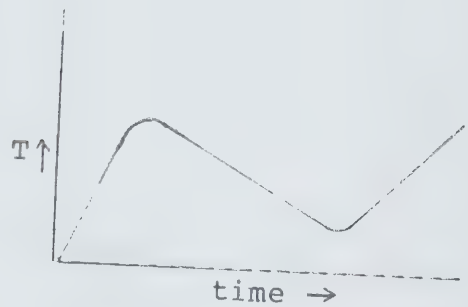
D 96

D 97

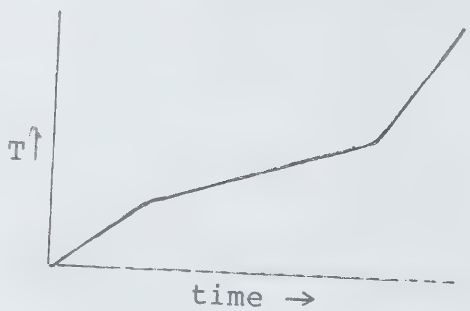
A)



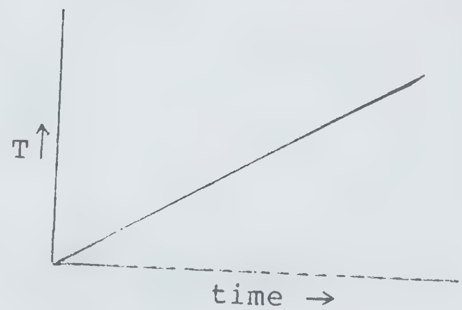

B)



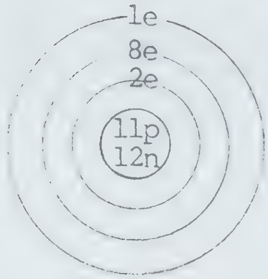

C)

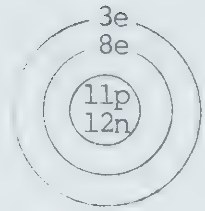


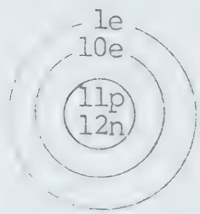

D)

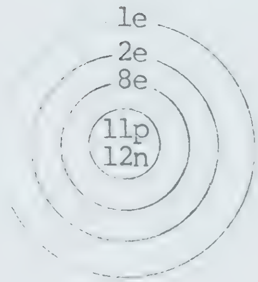


D 98

A) 


B) 


C) 


D) 


D 99

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ |
| 1s | 2s | $2p_x$ | $2p_y$ | $2p_z$ | 3s | $3p_x$ | $3p_y$ | $3p_z$ |

D 100

A)

| | | | | | |
|---|---|---|---|---|---|
| $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow$ |
| 1s | 2s | $2p_x$ | $2p_y$ | $2p_z$ | 3s |

B)

| | | | | | | |
|---|---|---|---|---|---|---|
| $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow$ | $\uparrow$ | $\uparrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ |
| 1s | 2s | $2p_x$ | $2p_y$ | $2p_z$ | 3s | 3p |

C)

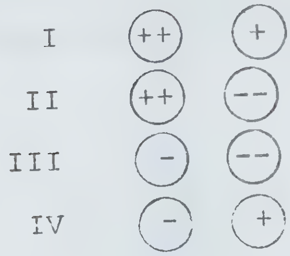
| | | | | | |
|---|---|---|---|---|---|
| $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow$ |
| 1s | 2s | 2p | 2d | 3s | 3p |

D)

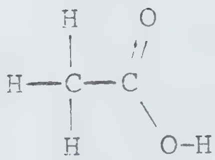
| | | | | | |
|---|---|---|---|---|---|
| $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow\downarrow$ | $\uparrow$ |
| 1s | 2s | 2p | 3p | 3s | 3p |

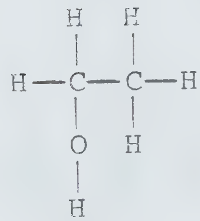
D 101 $\underset{1s}{\underline{\uparrow\downarrow}}$ $\underset{2s}{\underline{\uparrow\downarrow}}$ $\underset{2p_x}{\underline{\uparrow\downarrow}}$ $\underset{2p_y}{\underline{\uparrow\downarrow}}$ $\underset{2p_z}{\underline{\uparrow\downarrow}}$ $\underset{3s}{\underline{\uparrow\downarrow}}$ $\underset{3p_x}{\underline{\uparrow}}$

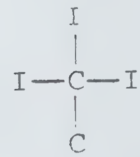
D 102

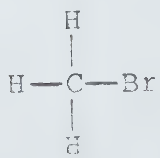



D 103

I) 

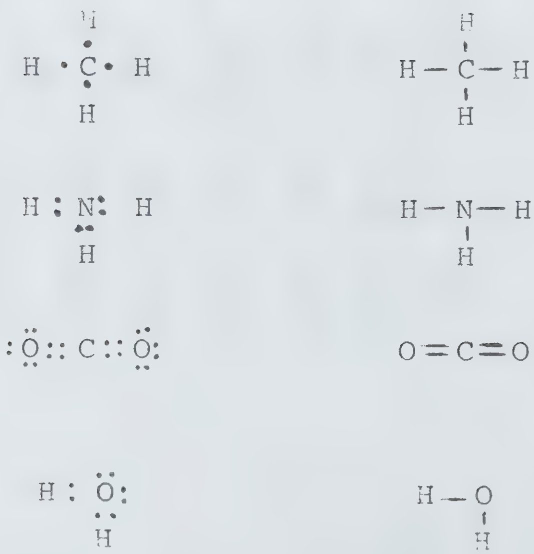
II) 

III) 

IV) 

V) 

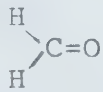
D 104

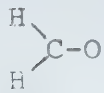


D 105

A) H - C = O - H

B) H = C = O - H

C) 

D) 

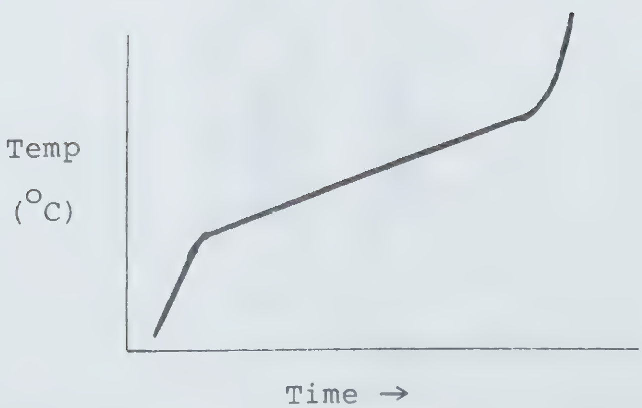
D 106

| | | | | | |
|---|---|---|---|---|---|
| A | | | | | B |
| C | D | E | F | G | H |
| I | J | K | L | M | N |

D 107

( ℓ )

D 108



D 109 molecules compared to carbon dioxide ($CO_2$) gas molecules $\left(\frac{v_{H_2O}}{v_{CO_2}}\right)$ at the same temperature?

D 110

A) $\frac{\uparrow\downarrow}{3s}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow}{3p}$

B) $\frac{\uparrow}{3s}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow\downarrow}{3p}$

C) $\frac{\uparrow}{3s}\ \frac{\uparrow}{3p}\ \frac{\uparrow}{3p}\ \frac{\uparrow}{3p}$

D) $\frac{\uparrow\downarrow}{3s}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow}{3p}\ \frac{\uparrow}{3p}$

D 111

A) $\frac{\uparrow\downarrow}{3s}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow}{3p}$

B) $\frac{\uparrow}{3s}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow\downarrow}{3p}$

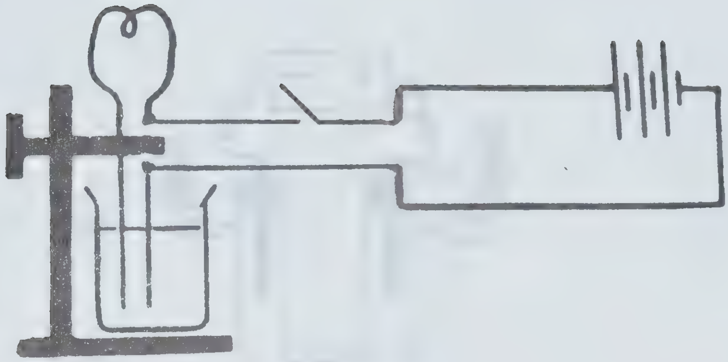
C) $\frac{\uparrow}{3s}\ \frac{\uparrow}{3p}\ \frac{\uparrow}{3p}\ \frac{\uparrow}{3p}$

D) $\frac{\uparrow\downarrow}{3s}\ \frac{\uparrow\downarrow}{3p}\ \frac{\uparrow}{3p}\ \frac{\uparrow}{3p}$

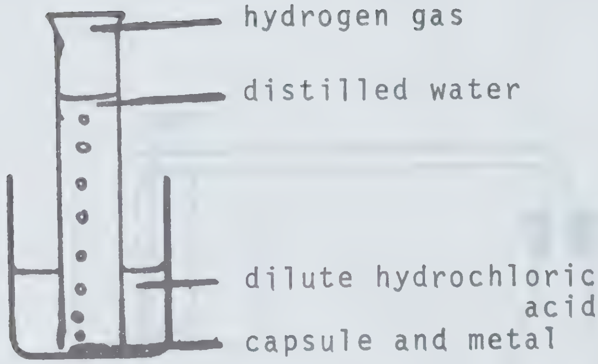
D 112

$$\lambda = \frac{h}{mc}$$

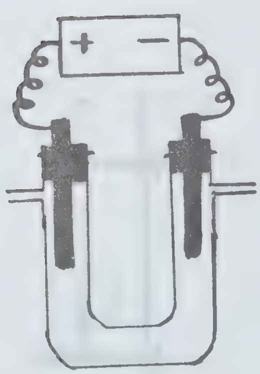
D 150



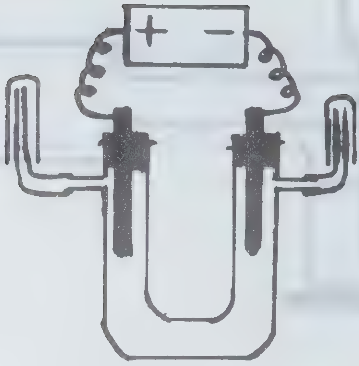
D 151



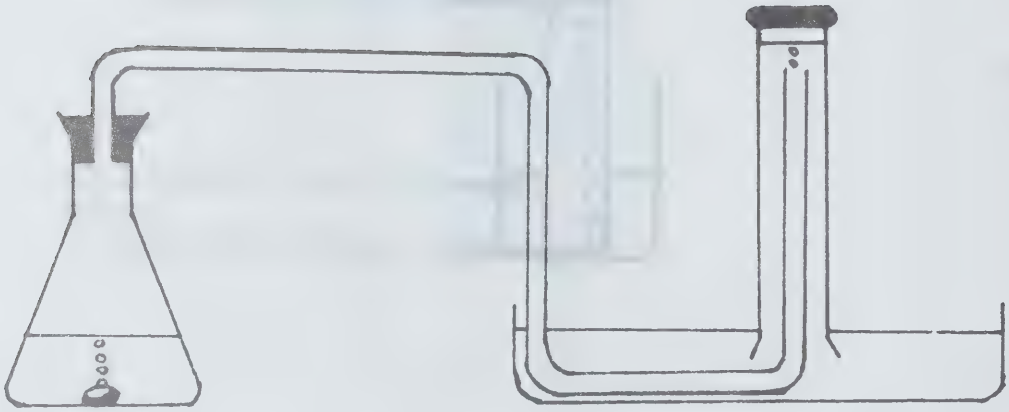

D 152



D 153

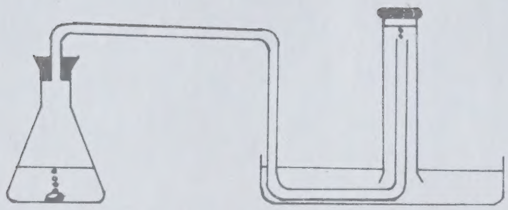


D 154

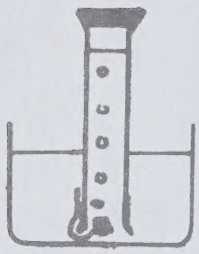


D 155

D 156

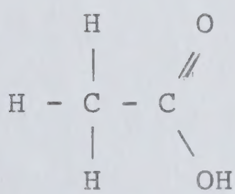


D 157

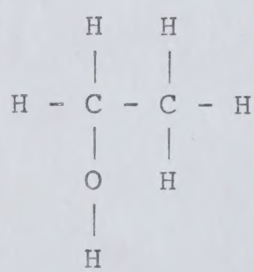


D 158

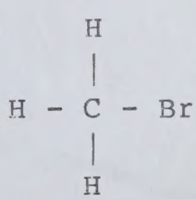
I)



II)



III)



IV)